Latvijas Lauksaimniecības universitāte

ELEKTRONIKAS UN DATORZINĀTŅU INSTITŪTS

projekta

"Robotizētas nezāļu ierobežošanas iekārtas izveide"

NOSLĒGUMA PĀRSKATS

Līguma nr. : 18-00-A01612-000024

Projekta partneri: LLU Augu aizsardzības zinātniskais institūts "Agrihorts"
LLU Tehniskā fakultāte
Elektronikas un datorzinātņu institūts
SIA "Lejasvagaļu dārzs"
J. Lipska saimniecība "Absolūts Ēd"
ZS "Atvases

Projekta īstenošanas periods: 01.01.2019 - 28.02.2021.

Kopējās projekta izmaksas: 472`500 EUR

2021

Saturs

Tekstā lietoto saīsinājumu tabula

LLU	Latvijas Lauksaimniecības universitāte
TF	Latvijas Lauksaimniecības universitātes Tehniskā fakultāte
EDI	Elektronikas un datorzinātņu institūts
TTL	Tranzistora-tranzistora loģika (vadības signāls)
CPU	Datora centrālais procesors (*Central Processing Unit*)
GNSS	Globālā navigācijas satelītu sistēma
GPS	Globālā pozicionēšanas sistēma
RTK	Real-time kinematic (Reāllaika kinemātika)
PCB	Iespiedshēmas plate (*Printed Circuit Board*)
AE	Augu attīstības etaps

Projekta apraksts un sasniedzamais mērķis

Nezāles ir viens no būtiskākajiem faktoriem, kas samazina ražu un palielina ražošanas izmaksas augkopībā, it sevišķi dārzeņu, ogu un garšaugu audzēšanā izmantojot bioloģiskās metodes. Manuāla nezāļu ravēšana arī būtiski samazina saimniecības ekonomisko efektivitāti un padara ražošanu atkarīgu no svārstībām darbaspēka tirgū.

Lai arī tirgū ir pieejamas tehnoloģijas, kas daļēji risina nezāļu problēmu (piem., augsnes sagatavošana, starpvagu kultivēšana), tehnoloģijas nezāļu ierobežošanai tuvu kultūraugam joprojām ir izstrādes stadijā arī citās valstīs, tādēļ pamatā tiek izmantota ķīmiska nezāļu ierobežošana - izmantojot pesticīdus, bet bioloģiskajās saimniecībās - roku darbs. Īpaši aktuāli tas ir kultūraugiem, kas slikti konkurē ar nezālēm un ir jutīgi pret mehanizētu apstrādi (piem., burkāni, bietes, redīsi). Lai uzlabotu kultūrauga konkurenci ar nezālēm agrās attīstības stadijās var veikt diedzēšana substrātā un uz lauka izstādīt dēstus. Tas gan ir piemērots tikai atsevišķiem kultūraugiem un ir saistīts ar papildus roku darbu. Līdzīgi ir ar mulčējamo materiālu izmantošanu (piem., plēves, biomasa) – šī metode ir piemērotas tikai daļai no kultūraugiem.

Bioloģiskajās saimniecībās roku darba aizvietošana un ražošanas mehanizācija dotu būtisku ieguldīju ražošanas attīstībai savukārt saimniecībās, kas izmanto pesticīdus būtu iespējams samazināt to lietojumu, kas ir īpaši aktuāli šobrīd, kad ES politika ir vērsta uz pesticīdu apjoma samazināšanu un to izraisīto veselības risku samazināšanu.

Projekta mērķis: izstrādāt nezāļu ierobežošanas iekārtu, kas spēj autonomi pārvietoties pa lauku, identificēt nezāles un atšķirt tās no kultūrauga, kā arī izmantojot augstas enerģijas lāzera vai precīzi pozicionēta mehāniskā agregāta palīdzību, iznīcināt nezāli vai būtiski traucēt tās turpmāko augšanu.

Projektā plānotie rezultāti:

- projekta ietvaros tiks izstrādāta jauna augsti tehnoloģiska iekārta;
- tiks sagatavotas 3 populārās publikācijas nozares izdevumos;
- tiks sagatavotas 2 zinātniskās publikācijas starptautiskos izdevumos;
- projekta otrajā gadā izstrādātā iekārta tiks prezentēta 3 lauku dienās.

Projektā iesaistīto partneru uzdevumi un atbildības jomas

Projekta īstenošanā iesaistīti seši partneri, kuriem tika paredzēti uzdevumi atbilstoši to kompetencei un iepriekšējai pieredzei. Projekta kopējo vadību veica LLU Augu aizsardzības zinātniskais institūts `Agrihorts`, un katrs no partneriem plānoja un realizēja savas aktivitātes atbilstoši kopējam projekta plānam. Zemāk uzskaitīti galvenie projekta ietvaros paveiktie uzdevumu bloki katram partnerim.

LLU Augu aizsardzības zinātniskais institūts `Agrihorts`

Agrihorts veica augu audzēšanu siltumnīcas apstākļos, fotogrāfiju uzņemšanu gan uz lauka, gan siltumnīcā audzētajiem augiem, attēlu apstrāde un anotēšanu. Sadarbībā Tehnisko fakultāti veikti augu apstrādes ar lāzeru eksperimenti. Sadarbībā ar EDI veikti robota navigācijas sistēmas testi. Agrihorts nodrošināja informācijas apmaiņu un aktivitāšu koordinēšanu partneru starpā. Kopā ar pārējiem partneriem veikta iekārtas atsevišķo moduļu un prototipa testēšanu laboratorijas un lauka apstākļos.

LLU Tehniskā fakultāte

Tehniskā fakultāte veica mehānisko un elektronisko daļu izstrādi, rasēšanu un izgatavošanu, tajā skaitā metāla detaļu metināšanu un elektronisko iespiedshēmu lodēšanu. Veikta centrālās vadības un izpildmehānismu iegultā programmēšana, lietotāja saskarnes izveide prototipa vadīšanai ar planšetes palīdzību. Izgatavots lāzera iedarbības novērtēšanas stends uz roborokas manipulatora UR10 bāzes. Sadarbībā ar EDI veikta navigācijas iekārtu testēšana.

Elektronikas un datorzinātņu institūts (EDI)

EDI veica attēlu anotēšanas rīka izstrādi, augu atpazīšanas algoritmu izstrādi un konvolūciju neironu tīklu apmācību, navigācijas algoritmu izstrādi, kā arī atsevišķo programmatūras bloku kopējās komunikācijas ietvara izveidi. Sadarbībā ar Agrihortu un Tehnisko fakultāti veikta navigācijas iekārtu testēšana. Sadarbībā ar Agrihortu veikta dažādu atpazīšanas algoritma versiju testēšana.

SIA "Lejasvagaļu dārzs"

Saimniecība nodrošināja nepieciešamās platības ar ķirbju un cukīni augiem agrās attīstības stadijās. Tika veikta nepieciešamā augsnes apstrāde un sagatavošana sējai un kultūraugu sēja, veicot to atkārtoti vairākas reizes sezonā. Pēc Agrihorta norādījumiem tika veikta mehāniska vai manuāla nezāļu ierobežošana. Saimniecība arī veica kultūraugu fotografēšanu, izmantojot sagatavoto aprīkojumu. Kopā ar pārējiem partneriem veikta prototipa novērtēšana lauka apstākļos un rekomendāciju sniegšana uzlabojumiem.

J. Lipska saimniecība "Absolūts Ēd"

Saimniecība nodrošināja nepieciešamās platības ar rutku un redīsu augiem agrās attīstības stadijās. Tika veikta nepieciešamā augsnes apstrāde un sagatavošana sējai un kultūraugu sēja, veicot to atkārtoti vairākas reizes sezonā. Pēc Agrihorta norādījumiem tika veikta mehāniska vai manuāla nezāļu ierobežošana. Saimniecība arī veica kultūraugu fotografēšanu, izmantojot sagatavoto aprīkojumu. Kopā ar pārējiem partneriem veikta prototipa novērtēšana lauka apstākļos un rekomendāciju sniegšana uzlabojumiem.

ZS "Atvases

Saimniecība nodrošināja nepieciešamās platības ar biešu un burkānu augiem agrās attīstības stadijās. Tika veikta nepieciešamā augsnes apstrāde un sagatavošana sējai un kultūraugu sēja, veicot to atkārtoti vairākas reizes sezonā. Pēc Agrihorta norādījumiem tika veikta mehāniska vai manuāla nezāļu ierobežošana. Saimniecība arī veica kultūraugu fotografēšanu, izmantojot sagatavoto aprīkojumu. Kopā ar pārējiem partneriem veikta prototipa novērtēšana lauka apstākļos un rekomendāciju sniegšana uzlabojumiem.

Papildus augstāk uzskaitītajam, iekārtas atsevišķo moduļu un prototipa dažādas gatavības stadiju testēšanā piedalījās visi zinātniskie partneri, katram sniedzot ieguldījumu savas kompetences sfērā. Partneru starpā notika aktīva komunikācija gan divpusēji, gan iesaistoties vairākiem partneriem, lai risinātu kādu izstrādes aspektu. Ļoti svarīga bija zemnieku saimniecību iesaiste projektā, jo tika sniegti vērtīgi norādījumi par prototipa, kā arī atsevišķo komponentu un tehnoloģiju piemērotību konkrētās saimniecības agrotehniskajām prasībām. Tāpat tika saņemta atgriezeniskā saite par vajadzīgajiem uzlabojumiem fotografēšanas aprīkojumam un fotogrāfiju uzņemšanai kopumā.

Pirmajā sezonā tika aktīvi diskutēts ar saimniecībām par nepieciešamajiem tehniskajiem risinājumiem dažādām kultūraugu sugām, kas tālāk tika ņemts vērā prototipa izstrādē, piemēram, izveidots regulējamu riteņu atstatums, lai varētu strādāt ar dažādu kultūraugu rindu atstatumu, kā arī izveidots regulējams ierobežošanas agregātu augstums, kas ļauj strādāt gan ar vagām, gan uz plakana lauka.

Projekta partneru kontaktinformācija:

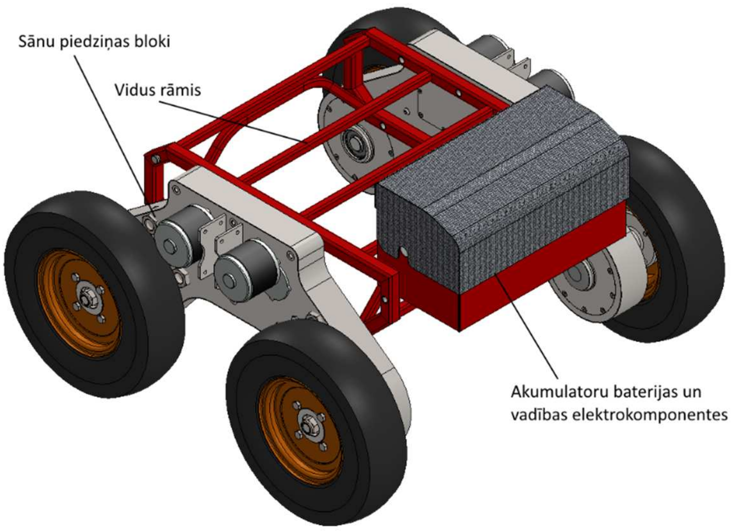
- LLU Augu aizsardzības zinātniskais institūts `Agrihorts`, Jānis Jaško, janis.jasko@llu.lv
- LLU Tehniskā fakultāte, Vitālijs Osadčuks, vitalijs.osadcuks@llu.lv
- Elektronikas un datorzinātņu institūts, Kaspars Sudars, sudars@edi.lv
- SIA "Lejasvagaļu dārzs", Sanita Vīķe, sanita.vike@inbox.lv
- J. Lipska saimniecība "Absolūts Ēd", Juris Lipskis, aimx@tvnet.lv
- ZS "Atvases", Andris Mangulis, andris.mangulis@inbox.lv

1. Iekārtas mobilās platformas un nezāļu iznīcināšanas mehānisko daļu projektēšana un konstruēšana

Nezāļu ierobežošanas iekārta projektēta kā autonoma, pašbraucoša iekārta, kas izstrādāta ar salīdzinoši kompaktiem izmēriem. Iekārtas konstrukcija veidota tā, lai to varētu ērti pielāgot vajadzīgajam dobes platumam. Lai nodrošinātu labu pārgājamību un vadāmību, izveidota visu riteņu neatkarīga piedziņa, t.i. katru riteni piedzen savs elektromotors. Piedziņas mehānisms izveidots noslēgts, lai nepieļautu apkārtējās vides (lietus, putekļu utt.) nokļūšanu uz piedziņas elementiem.

Projekta laikā sākotnējie pētījumi, augu paraugu fotografēšana veikta uz jau iepriekš LLU izstrādātas robotizētas platformas. Tomēr apzinot potenciālās pilnveidošanas iespējas, sākotnējās platformas vietā uzprojektēta un izveidota jauna platforma, kura tālāk aprīkota ar visiem nepieciešamajiem elementiem nezāļu atpazīšanas un ierobežošanas funkciju veikšanai.

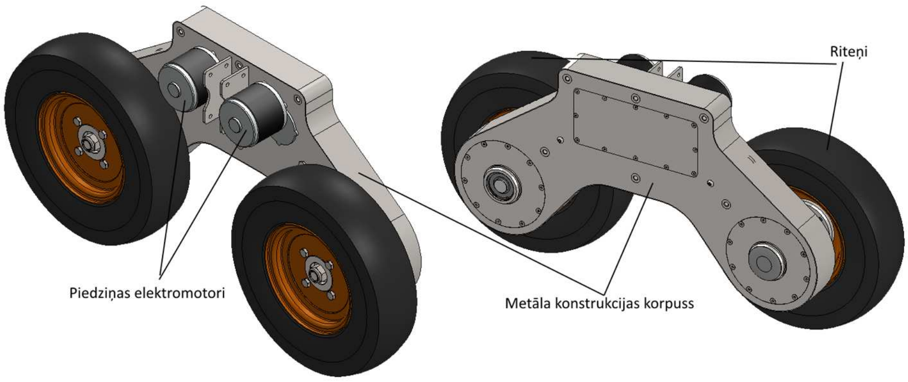
1.1. Sākotnējās platformas apraksts



1. att. Sākotnējās platformas kopskats

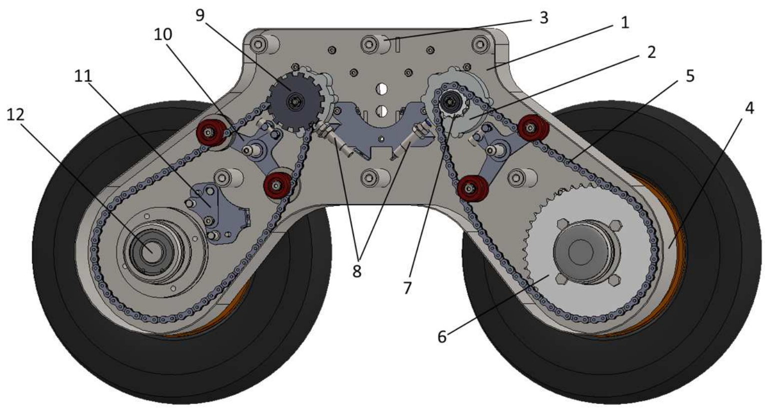
Sākotnējās platformas konstrukcijas pamatā bija divi neatkarīgi sānu piedziņas bloki, kas savā starpā sastiprināti ar metāla konstrukcijas rāmi. Pie metāla konstrukcijas rāmja pieskrūvēts nodalījums platformas akumulatora bateriju un elektrovadības elementu nostiprināšanai.

Platformas sānu bloku pamatā ir no metāla izgatavots korpuss, kurā ievietoti visi piedziņas pārvada elementi. Korpusā iegultņotas divas asis, uz kurām stiprinās piedziņas riteņi, savukārt korpusa augšdaļā ir izveidotas vietas piedziņas elektromotoru nostiprināšanai.



2. att. Sānu bloki

Katra riteņu piedziņa tiek nodrošināta ar ķēdes pārvadu no sava līdzstrāvas elektromotora. Elektromotori, savukārt nekustīgi pieskrūvēti sānu bloku korpusam. Riteņu asis divos lodīšu gultņos iegultņoti speciāli izveidotos gultņu korpusos.



3. att. **Sānu bloka konstrukcija:** 1 – Sānu bloku pamatne; 2 – Elektromotori ar reduktoriem; 3 – Pamatņu stiprinājuma elementi; 4 – Apvalki; 5 – Piedziņas ķēdes; 6 – Lielā piedziņas zvaigznīte; 7 – Mazā piedziņas zvaigznīte; 8 – Rotācijas ātruma sensori; 9 – Apgriezienu zobu disks; 10 – Ķēžu spriegotājmehānisms; 11 – Bremžu mehānisms; 12 – Piedziņas ass.

Analizējot platformas izmantošanas, kā arī apkopes un remonta iespējas, noteiktas vairākas konstrukcijas uzlabošanas iespējas, kas arī iestrādātas nākamajā platformas konstrukcijā. Galvenās šīs konstrukcijas nepilnības noteiktas sekojošos elementos.

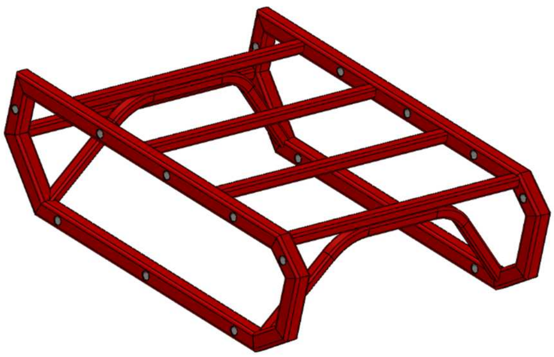
Pirmkārt **ķēdes spriegošanas** iespējas. Kā zināms, ekspluatācijas laikā ķēde var stiepties, kas izsauc nepieciešamību periodiski pārbaudīt ķēdes spriegojumu, kā arī nepieciešamības gadījumā, to nospriegot. Šajā konstrukcijā izveidots spriegošanas mehānisms sānu bloku iekšpusē ar salīdzinoši neērtu piekļūšanas iespēju. Tāpat korekta spriegošanas mehānisma izveide paredz, ka ķēde tiek spriegota tajā ķēdes posmā, kas nav noslogots. Tomēr šīs platformas konstrukcija paredzēta braukšanai abos virzienos, līdz ar to, atkarībā no braukšanas virziena tiks nospriegots viens vai otrs ķēdes posms. Ar esošo ķēdes spriegošanas mehānismu, tika mēģināts nodrošināt korektu ķēdes spriegojumu neatkarīgi no platformas braukšanas virziena, tomēr platformas virziena maiņa izsauca spriegošanas mehānisma pārvietošanos ar troksni. Nākamajā platformas versijā šis spriegošanas mehānisms tiks aizstāts ar pavisam savādāku spriegošanas konstrukciju.

Bremžu mehānisms. Šajā platformas konstrukcijā bija izstrādāts lentu bremžu mehānisms, tomēr sākotnējā platformas ekspluatācija parādīja, ka bremžu mehānismam nav būtiskas lomas. Sakarā ar to, ka izvēlēti elektromotori ar reduktoriem, tad platformas kustība bez elektromotoru piedziņas ir apgrūtinoša. Elektromotori ar reduktoriem praktiski nobremzē platformu, un tas ir pietiekoši, lai platformu noturētu vajadzīgajā vietā pat uz nelieliem slīpumiem. Tādēļ nākamajā platformas versijā bremžu mehānismi netiks uzstādīti, tomēr kā papildus iespēja tā netiek izslēgta.

4. att. Bremžu mehānisms.

Riteņu griešanās ātruma noteikšana. Riteņu griešanās ātrumu nepieciešams noteikt, lai varētu vadīt un nodrošināt atbilstošu elektromotoru jaudu konkrētiem riteņu saķeres apstākļiem. Platformas konstrukcijā bija ieplānots, ka riteņiem, kam ir labāka saķere, tiks pievadīts lielāks griezes moments, nekā tiem, kam ir sliktāka saķere. Esošā konstrukcija paredzēja salīdzinoši dārgu apgriezienu devēju uzstādīšanu, kā arī speciālu izciļņu disku uzstādīšanu uz elektromotora izejošās vārpstas. Nākamās versijas platformai, principiāli šī funkcija tiks atstāta, tomēr konstruktīvais izpildījums ir vienkāršots un uzlabots.

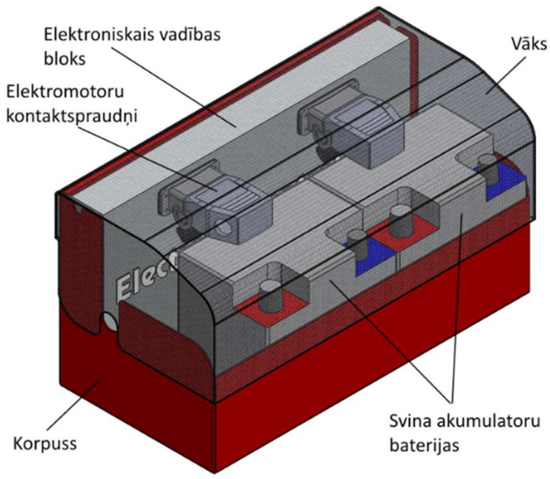
Vidusrāmja konstrukcija. Šākotnējā izpildījumā vidusrāmis izveidots kā neizjaucams, sametinātu profilu rāmis.



5. att. Vidus rāmja konstrukcija

Lai šādā izpildījumā izmainītu sānu bloku atstatumu, jeb t.i., lai pielāgotu platformu atšķirīgam dobes platumam, nepieciešams nomainīt visu rāmi. Gadījumos, ja potenciālajā saimniecībā tiek izmantoti dažādi dobes platumi, tas nav ērti no iekārtas izmantošanas viedokļa. Šī iemesla dēļ jaunās platforma konstruēta ar pavisam atšķirīgu un daudz ērtāku iespēju izmainīt starpvagu attālumu.

Akumulatoru baterijas, centrālais vadības bloks un atsevišķu elektromotoru vadības bloki novietoti kopējā kastē un piestiprināti pie vidusrāmja.



6. att. Platformas elektrokomponentes

Šajā konstrukcijā izmantoti svina skābes akumulatoru baterijas, kas ir salīdzinoši lēti un vienkārši, tomēr, ja aplūko tos no enerģijas blīvuma attiecībā pret baterijas masu, tad šis nav pats piemērotākais variants. Tādēļ jaunās konstrukcijas platformā izmantoti LiPO4 akumulatoru baterijas.

Autonomās platformas izpildījums uz projekta sākumu dots sekojošā attēlā:

7. att. V1 Platformas izskats uz projekta sākumu

Platformas tehniskie rasējumi šai versijai netiks uzrādīti, jo jaunās platformas konstrukcija lielākai daļu elementu ir atšķirīga no šīs sākotnējās versijas.

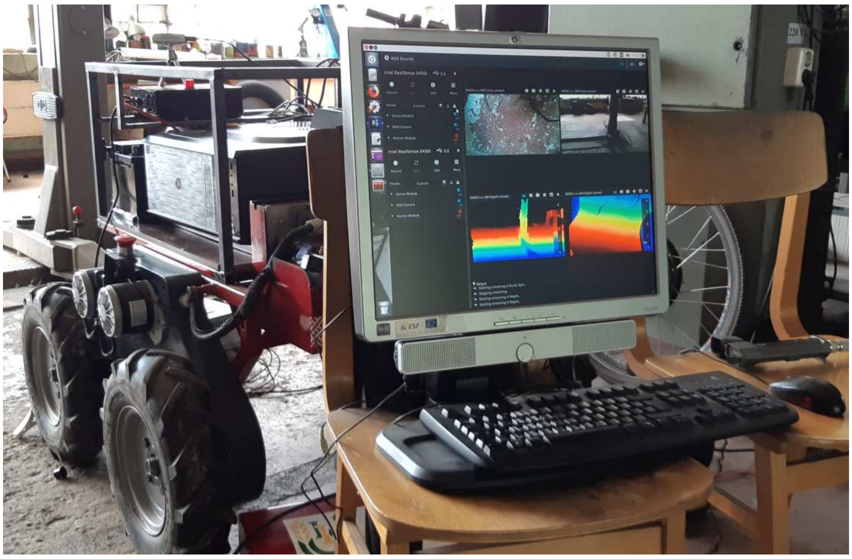
Lai ar esošo platformu varētu veikt projektā sākotnēji ieplānotos eksperimentus, kas pamatā bija augu fotografēšana, jeb augu datubāzes uzņemšana, esošā platforma tika aprīkota ar palīgaprīkojumu. Tika izveidots korpuss papildus akumulatoru, augu attēlu uzņemšanas datora, sprieguma pārveidotāju u.c komponenšu novietošanai, kā arī platformas apakšdaļā izveidota konstrukcija fotografēšanas kameras un papildus apgaismojuma uzstādīšanai. Tāpat platformas priekšpusē izveidots regulējams stiprinājums priekšējās kameras novietošanai.

Papildus aprīkojuma izgatavošana un uzstādīšana parādīta sekojošos attēlos:

8. att. Kameras un apgaismojuma stiprināšanas rāmja izveide

9. att. Korpusa izveide papildaprīkojuma novietošanai.

Iekārtu salāgošana un kameru testēšana laboratorijas apstākļos parādīta sekojošā attēlā:



10. att. Augu fotografēšanas kameru salāgošana un pārbaude

11. att. Sākotnējā platforma, kas pielāgota kultūraugu fotografēšanai.

Šādi izskatījās sākotnējā platforma, kad tā bija pielāgota kultūraugu fotografēšanai. Visas elektrokomponentes novietotas no atmosfēras apstākļiem pasargātā korpusā. Papildus uzstādītais akumulators ļauj fotografēšanas funkciju, kā arī fotogrāfiju saglabāšanu nodrošināt autonomi bez ārēja sprieguma padeves. Platformas priekšpusē novietotā kamera paredzēta, lai var uzņemt attēlus no vagas, pa kuru tiek braukts, tādā veidā, dodot iespēju pilnveidot vagas atpazīšanas funkciju. Sākotnējās platformas vadība notika ar distances vadības pulti, kas šajā gadījumā bija viedtālrunis ar atbilstošu aplikāciju. Platformas aprīkojuma korpusā tika uzstādīts arī monitors, kas lauka apstākļos ļāva kontrolēt un pārraudzīt augu fotogrāfiju uzņemšanas procesu.

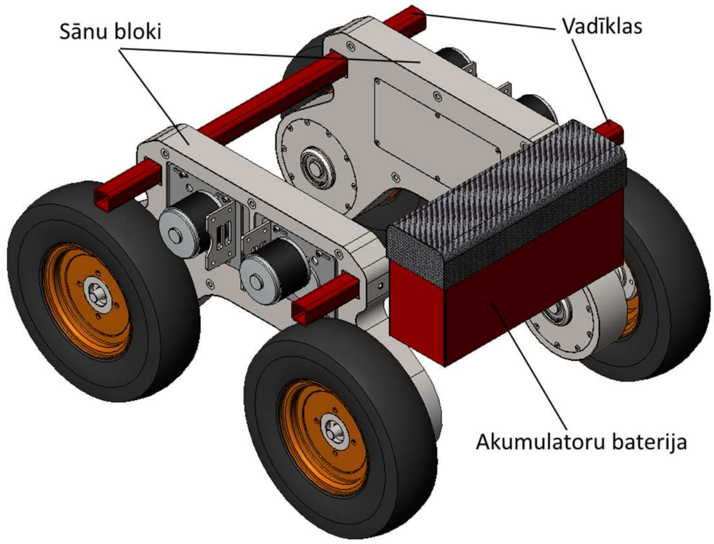
Sākotnējās platformas noslēdzošajā izmantošanas posmā, tās konstrukcija tika papildināta ar saules baterijām, papildus enerģijas iegūšanai. Šādā izpildījumā ievērojami palielinājās platformas ekspluatācijas laiks bez papildus uzlādēšanas.

12. att. Ar saules enerģijas paneli aprīkota platforma.

1.2. Mobilās platformas pielāgošana autonomai darbībai un nezāļu ierobežošanai

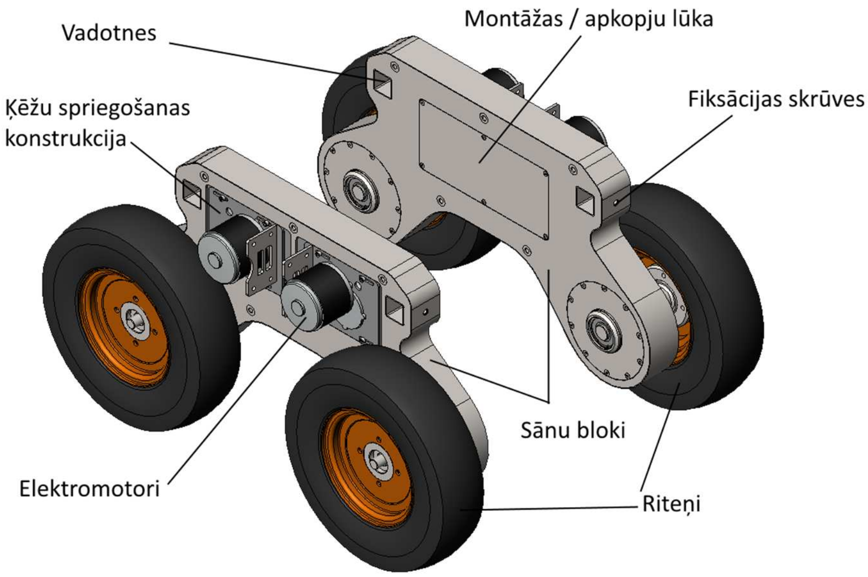
Paralēli sākotnējās platformas pilnveidošanai un izmantošanai, notika darbs pie uzlabotās nezāļu ierobežošanas platformas (V2) izstrādes. Tika izstrādāta jaunas konstrukcijas platforma, kas tāpat kā sākotnējā platformas versija, sastāvēja no diviem patstāvīgiem sānu blokiem. Atšķirībā no pirmās versijas, šai platformai, sānu bloki nebija pieskrūvējami pie vidusrāmja, bet gan tie sastiprināti ar divām sijām, kas ļauj ērti izmainīt sānu bloku savstarpējo atstatumu.

Lai šādu regulēšanas konstrukciju vārētu īstenot, tika ieviestas izmaiņas arī pašu sānu bloku konstrukcijās. Sānu blokos tika ieprojektētas vadotnes platformas sijām. Priekšstatam sekojošajā attēlā parādīts jaunās platformas (braucošās daļas) kopskats, un detalizācija tiks izklāstīta aiz tās.

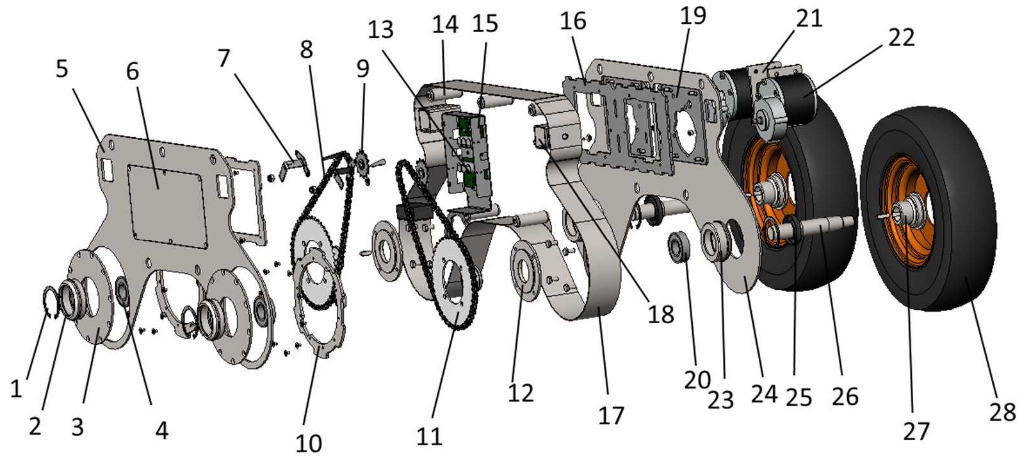


13. att. Jaunās platformas (V2) braucošās daļas konstrukcija

Kā redzams attēlā, platformas sānu bloki vairs nav pieskrūvēti nemainīga platuma vidusrāmim, bet gan nostiprināti uz divām vadīklām. Platformas platumu var viegli pielāgot. Maksimālās platformas platumu nosaka vadīklu garums. Platformas sānu bloku fiksāciju uz vadīklām nodrošina ar speciāli izveidotu kontrējošo skrūvju palīdzību, kas iestrādātas sānu blokos. Līdz ar to arī pašu sānu bloku konstrukcija ir ievērojami pamainījusies, salīdzinot ar sākotnējo V1 versiju.



14. att. Sānu bloku kopskats.



15. att. **Sānu bloka detalizācija:** 1. – Sprostgredzens; 2., 23. – Gultņu korpuss; 3. – Iekšējie rumbu vāki; 4., 20. – Gultnis; 5. – Bloka iekšējais sāns; 6. – Montāžas lūka; 7 – Apgriezienu devēja kronšteins; 8 – Ķēde; 9. – Dzenošais ķēžrats; 10. – Rumbu vāka kronšteins; 11. – Dzītais ķēžrats; 12. – Dzītā ķēžrata rumba; 13. – Elektromotoru draiveri; 14. – Sānu malu stiprinājuma elementi; 15. – Draiveru kronšteins; 16 – Elektromotoru vadotņu kronšteins; 17 – Sānu bloka apvalks; 18. – Vadotnes; 19. – Elektromotoru kronšteini / vadotnes; 24. – Bloka ārējais sāns; 25. – Blīvslēgs; 26. – Riteņa vārpsta; 27. – Riteņa rumba; 28. – Ritenis.

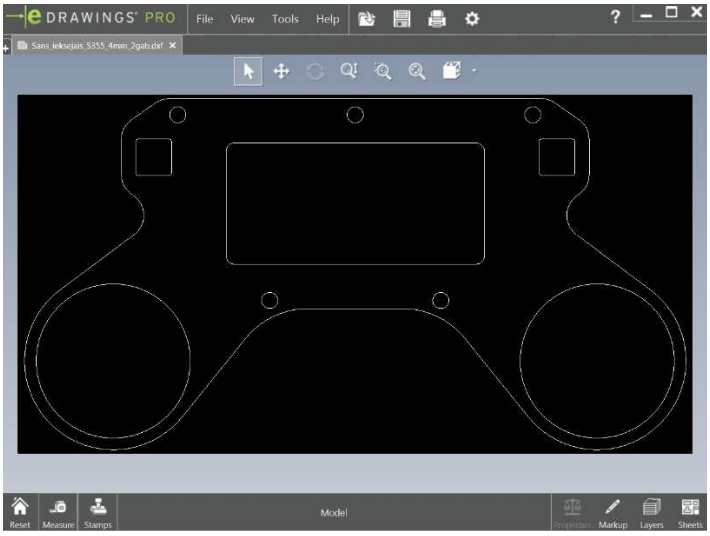
No visām iepriekšējā attēlā redzamajām detaļām, kā standartizēti izstrādājumi, kuri atbilstoši specifikācijai atrasti un iegādāti ir: elektromotori ar reduktoriem, abi piedziņas ķēžrati, ķēde, kā arī dažādi standartizētie izstrādājumi (skrūves, uzgriežņi, gultņi, sprostgredzeni, blīvslēgi, kā arī riepas un diski. Pārējās visas sastāvdaļas ir izprojektētas, uzrasētas un pasūtītas izgatavošanai vai izgatavotas paša spēkiem. Liela daļa elementu atbilstoši rasējumam izgriezti ar lāzergriešanas paņēmienu no S235 markas tērauda, atsevišķas detaļas izgrieztas no DC-01 tērauda loksnēm. Savukārt piedziņas vārpsta, gultņu korpusi, riteņu rumbas u.c. elementi izvirpoti no atbilstošu materiālu apaļdzelzs stieņiem vai biezsienu caurulēm. Piedziņas vārpstas materiāls C45 tērauds.

Konstrukcijas izgatavošanas galvenie etapi ir sekojoši. Sākotnēji visi elementi tiek uzprojektēti, uzrasēti un izveidots kopsalikuma rasējums, kurā rūpīgi novērtēts detaļu salāgojums, atstarpes starp detaļām, kā arī dažādu simetrijas asu un plakņu savstarpējais novietojums. Kopsalikuma rasējumā visas detaļas tiek izvietotas un saliktas tām paredzētajās vietās. Atsevišķi detaļu izmēri tiek piekoriģēti, paredzot dažādas detaļu deformācijas, konstrukcijas sametināšanas laikā. Kā arī tiek ievērtētas iespējamās detaļu izmēru izmaiņas pēc virsmu krāsošanas vai aizsargpārklājuma uznešanas.

Tālāk visas uzrasētās detaļas tiek sagrupētas vairākās daļās:

- Standartizētie elementi;
- Lāzerējamās detaļas
- Virpojamās / frēzējamās detaļas.

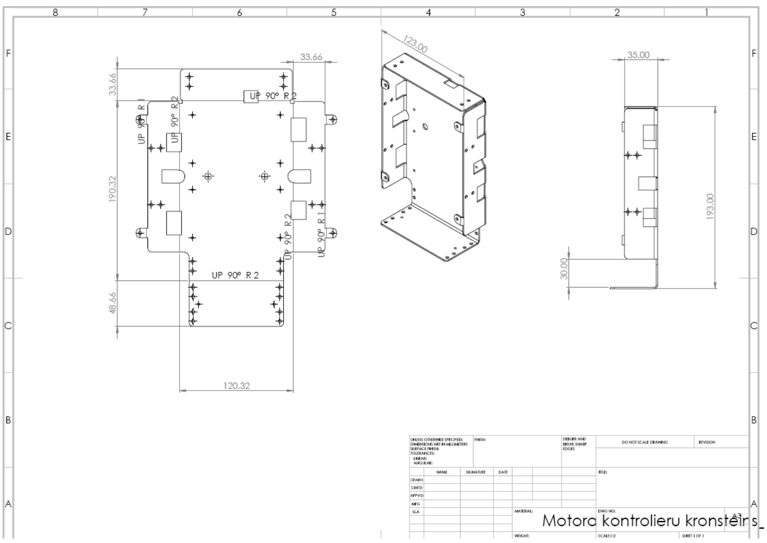
Atbilstoši detaļu tālākās izgatavošanas prasībām, tiek sagatavoti rasējumu faili atbilstošajos formātos. Piemēram, ar lāzergriešanu paredzēto detaļu izgatavošanai tiek sagatavoti DXF formāta faili atbilstošajos skatos. Faila nosaukums tiek atbilstoši marķēts. Pēc faila nosaukuma iespējams noteikt kas tā ir par detaļu, no kāda materiāla tā jāizgatavo, cik biezam jābūt materiālam, kā arī kāds ir izgatavojamo detaļu skaits. Ja pēc lāzergriešanas detaļu paredzēts vēl locīt, tad papildus DXF formāta failam, katrai detaļai vēl izstrādā rasējumu, kurā norādīta galvenā informācija, kas attiecas uz detaļu locīšanu. Parasti šādu informāciju detaļu izgatavotājam iesniedz PDF formāta failos. Savukārt, detaļām, kuras tiek izgatavotas virpošanas vai frēzēšanas ceļā, tiek izstrādāts atbilstoša detalizējuma rasējums vairākos skatos, lai pēc tā būtu iespējams konkrēto detaļu izgatavot. Atsevišķu detaļu rasējumu vai specifisko formātu failu attēli parādīti sekojošos attēlos:



16. att. DXF formāta faila paraugs, pēc kā tiek izgatavotas detaļas ar lāzergriešanas paņēmienu.

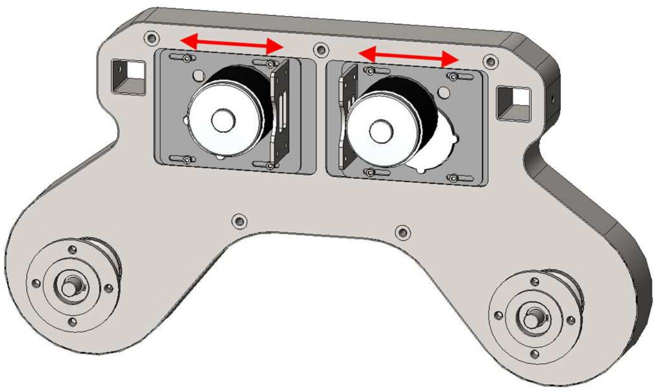
Konkrētā detaļa ir sānu bloka iekšējā mala. Pēc šī faila saturošās informācijas ir iespējams noteikt nepieciešamās griezuma līnijas, savukārt informācija par materiāla marku un biezumu tiek iekļauta nosaukumā, piemēram – "Sans_ieksejais_S355_4 mm_ 2gab".

Locīšanai paredzēto detaļu izgatavošanai papildus tiek sagatavots rasējums ar locīšanas līnijām.



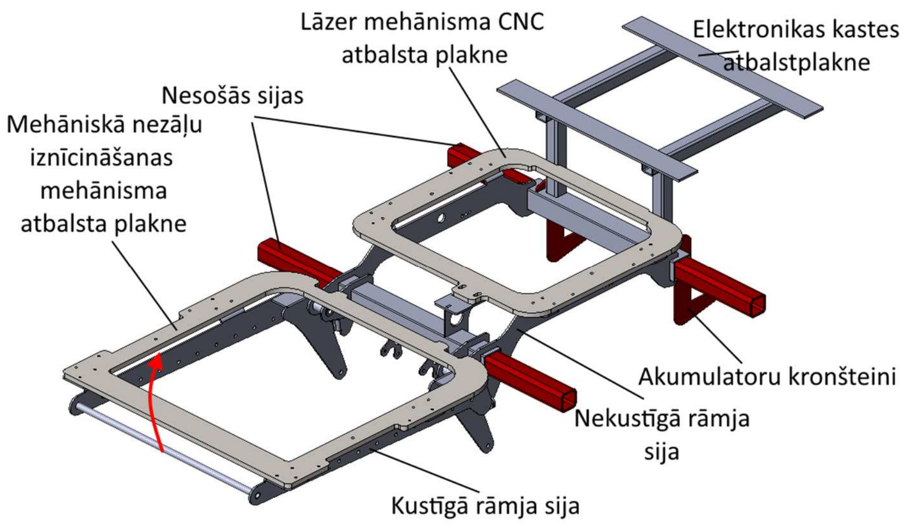
17. att. Rasējuma faili detaļām, kuras paredzēts locīt.

Apskatot sānu bloku konstrukciju, redzami vēl vairāki būtiski konstruktīvi uzlabojumi, salīdzinot ar iepriekšējās versijas platformas konstrukciju. Tā, piemēram, izveidots daudz praktiskāks un vienkāršāks dzenošo ķēžu spriegošanas mehānisms. Ķēžu spriegošana tiek organizēta pārvietojot elektromotorus kopā ar to stiprināšanas kronšteiniem pa speciālām vadvirsmām. Šāds tehniskais risinājums nodrošina daudz vienkāršāku piekļūšanu pie spriegošanas elementiem. Spriegošanu iespējams realizēt no ārpuses, līdz ar to nav pat jānoskrūvē nekādi vāki. Tāpat šāds spriegošanas paņēmiens ļauj vienlīdz labi platformu ekspluatēt abos braukšanas virzienos.



18. att. Ķēžu spriegošanas paņēmiens

Sānu bloki nostiprināti uz divām kvadrātcaurules profila biezsienas sijām. Šīs sijas tiek izmantotas arī visu pārējo elementu stiprināšanai. Tā, piemēram, uz sijām tiek nostiprināts centrālais CNC mehānismu atbalsta rāmis (skatīt attēlā).



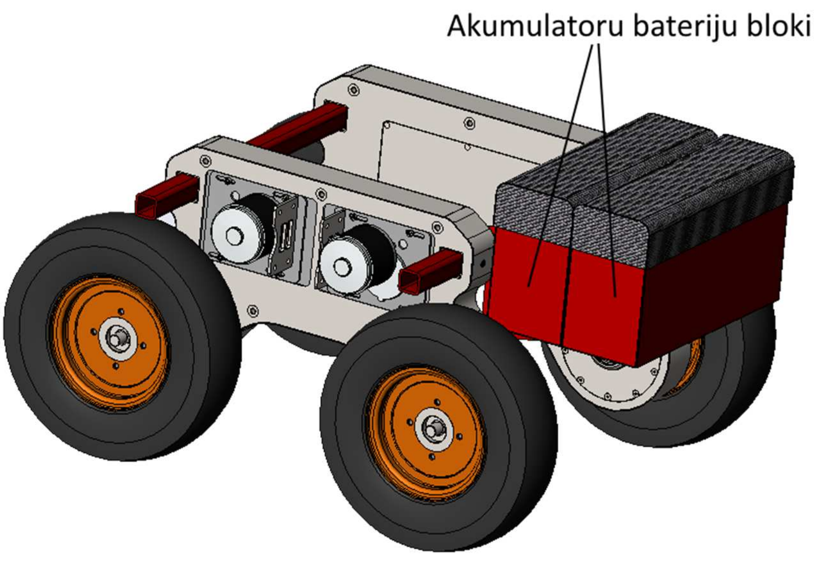
19. att. CNC mehānismu atbalsta rāmis

CNC Mehānismu atbalsta rāmis izveidots divdaļīgs. Viena daļa ir nosacīti nekustīga. Tā tiek nostiprināta uz atbalsta sijām. Uz nekustīgās rāmja daļas izveidota lāzera mehānisma CNC atbalsta plakne, kas izgatavota no 10 mm biezas tērauda loksnes. Uz šīs atbalsta plaknes tiek stiprināts CNC mehānisms, kas nodrošina nezāļu iznīcināšanas lāzera kustību trijās plaknēs. Atbalsta plakne nodrošina stabilu pamatni, pie kā pieskrūvēt CNC mehānismu.

Atbalsta rāmja otra daļa izveidota kustīga, jeb sagāžama uz augšu. Uz šīs rāmja daļas pieskrūvēta mehāniskā nezāļu iznīcināšanas CNC mehānisma atbalsta plakne. Rāmja priekšējā daļa izveidota sagāžama uz augšu tā iemesla dēļ, lai iekārtas transportēšanas laikā iespējams iegūt kompaktākus platformas izmērus.

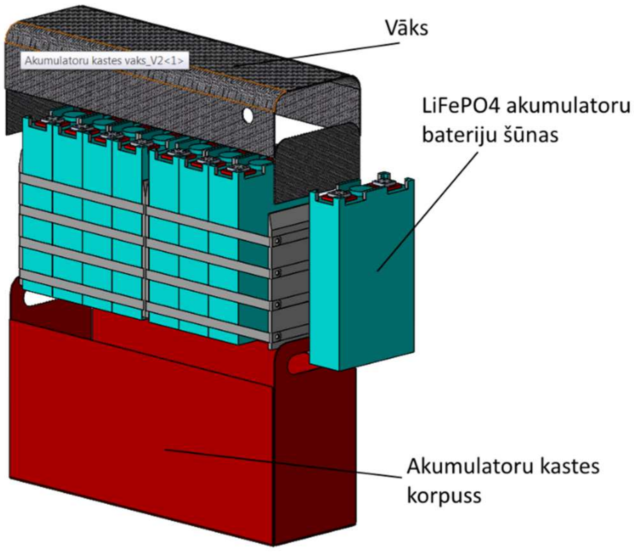
Tāpat pie nekustīgā rāmja piestiprināts arī rāmis akumulatoru bateriju, kā arī elektroniskās vadības elementu kastes nostiprināšanai. Nezāļu iznīcināšanas robota platformai ir uzstādīti divi atsevišķi akumulatoru bloki. Abi bloki novietoti viens pie otra un robota platformas vienā pusē. Katrā akumulatoru baterijas blokā ir ievietotas virknē slēgtas astoņas akumulatoru šūnas jeb divi komplekti pa 4 šūnām. Katra komplekta nominālais spriegums 12 V un ietilpība 100 Ah. Tā kā šūnas saslēgtas virknē, tad kopējais katra akumulatora bloka nominālais spriegums ir 24 V un ietilpība 100 Ah.

Abi akumulatoru bateriju bloki novietoti platformas vienā pusē. Šāds izvietojums izvēlēts tādēļ, lai līdzsvarotu slodzi uz platformas riteņiem, jo platformas otrā pusē novietots CNC mehānisms ar mehānisko nezāļu iznīcinātāju. Katrs akumulatoru bloks darbina savu sistēmu, tā, piemēram, viens akumulatoru bloks paredzēts platformas piedziņas mehānisma darbināšanai, t.i. elektromotoru, motoru draiveru un centrālā vadības bloka darbināšanai. Savukārt otrs akumulatoru bloks nodrošina elektroapgādi CNC mehānismiem, to draiveriem, lāzera nezāļu iznīcināšanas iekārtas darbībai, kā arī kultūraugu atpazinēja vadības elementu darbībai.



20. att. Akumulatoru bateriju bloku novietojums uz robota platformas.

Katrs akumulatoru bloks ir atsevišķi noņemams, kā arī to var atsevišķi atvienot no elektroķēdes. Arī akumulatoru uzlāde notiek atsevišķi pa akumulatoru blokiem, lietojot ārēji pieslēdzamu 24 V līdzstrāvas impulsu lādētāju.

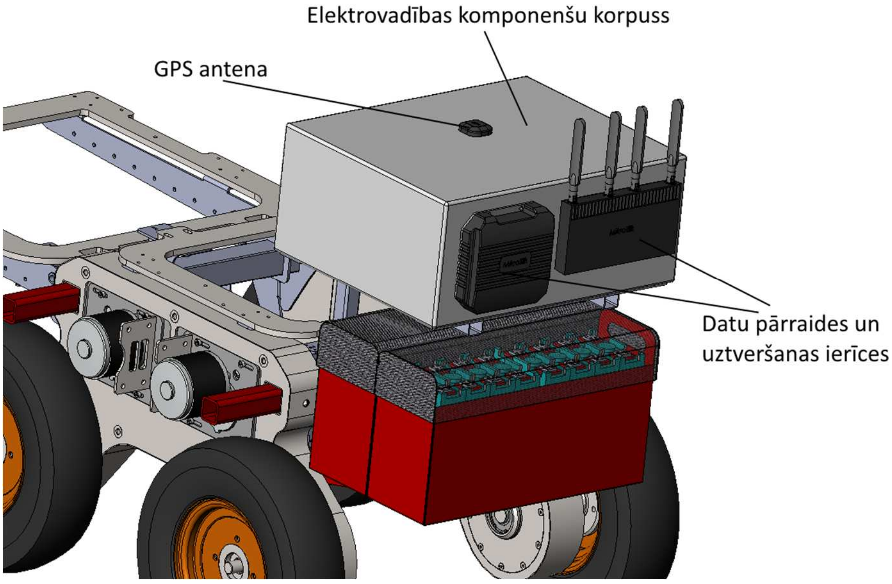


21. att. Akumulatora bateriju bloka sastāvdaļas

Akumulatoru bateriju lādētājs parādīts sekojošā attēlā. Lādētājs ir pieslēdzams 220 V tīklam un atsevišķi katram akumulatoru baterijas blokam.

22. Att. Akumulatoru bateriju lādētājs POW 24V 20A -D1

Pēc tehniskās specifikācijas šis lādētājs paredzēts konkrētā akumulatora veida lādēšanai un lādēšanas spriegums atbilst akumulatoru bloka nominālajam spriegumam. Akumulatora lādētājs nav piestiprināts robota platformai, bet gan tas atrodas robota platformas paredzētajā lādēšanas vietā. Tādā veidā nav nepieciešamība visu darba laiku vadāt līdzi lieku smagumu, kuru faktiski izmanto tikai lādēšanas laikā.



23. Att. Elektrovadības komponenšu kaste

Virs akumulatoru bateriju blokiem izveidots rāmis elektrovadības kastes stiprināšanai. Par elektrovadības kasti izmantota standarta elektroinstalācijas kaste. Šajā kastē ievietoti gan sprieguma pārveidotāji, gan CNC mehānismu visu sešu motoru draiveri, gan dators, kas atbild par kultūraugu atpazīšanu un CNC mehānismu vadīšanu, gan arī platformas sānu bloku centrālā vadības plate, kas dod signālus uz motoru draiveriem. Robota platformas ieslēgšanai uz elektrovadības kastes novietotas trīs pogas.

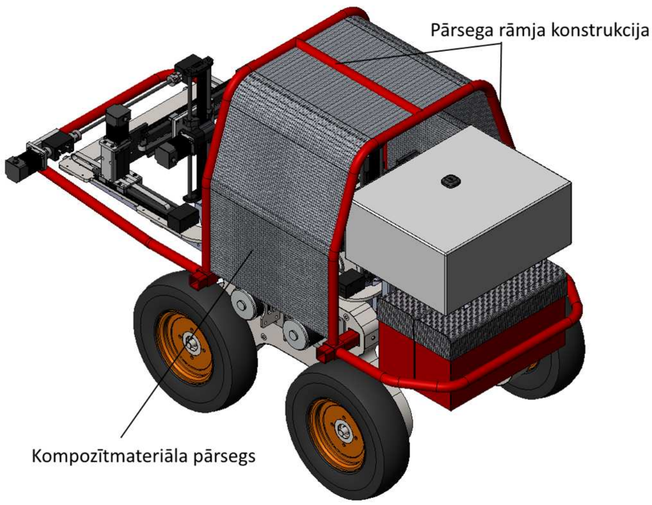
24. att. Robota platformas ieslēgšanas pogas

Atsevišķa poga izveidota lāzera nezāļu iznīcināšanas mehānisma elektroapgādei, jeb kā drošības elements, lai iekārtas demonstrēšanas laikā būtu iespēja atslēgt iekārtas lāzeri. Otra poga padod spriegumu uz CNC mehānismiem un to vadības draiveriem. Savukārt, trešā poga, kas izveidota kā drošības poga, paredzēta sprieguma padevei un atslēgšanai no piedziņas elementiem – elektromotoriem. Sistēmas kļūmes vai nesankcionētu darbību gadījumā, iespējams nospiest šo pogu un iekārta automātiski apstājās. Prasība pēc šāda drošības elementa ir jebkuram autonomam pašgājēj mehānismam.

Pie elektrovadības kastes (no ārpuses) piemontēti arī rūteri un viena no GPS antenām. Elementu pievienošana kastes ārpusei vairāk saistīts ar pārraidīto signālu labāku uztveršanu un pārraidi.

Bez GPS antenas, kas uzmontēta uz elektrovadības kastes, robota platformai uzstādīta vēl viena GPS antena. Divu antenu novietojums uz platformas, ļauj precīzāk pozicionēt platformu dabā.

Iekārtas projektēšanas noslēgumā, tika izstrādāts pārsegs, kas paredzēts iekārtas darbīgo daļu aizsargāšanai no nelabvēlīgiem apkārtējās vides faktoriem.

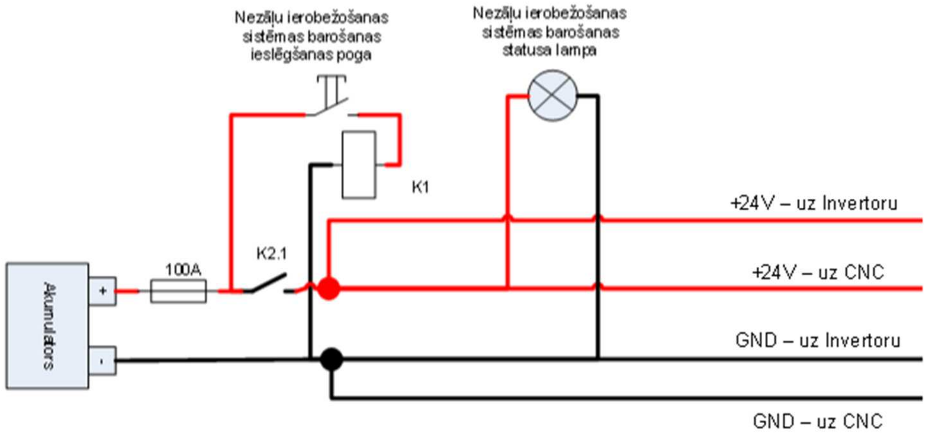


25. att. Iekārtas kopskats ar pārsega elementiem.

Iekārtas pārsegu veido noņemama metāla rāmja konstrukcija, pie kā vidusdaļā pieskrūvēts atbilstošas formas kompozītmateriāla pārsegs. Robota platformas priekšējā un aizmugurējā daļa paredzēts pārsegt ar elastīgu pārsegu, lai to varētu ērti salocīt brīžos, kad jātiek pie vadības elementiem vai izpildmehānismiem.

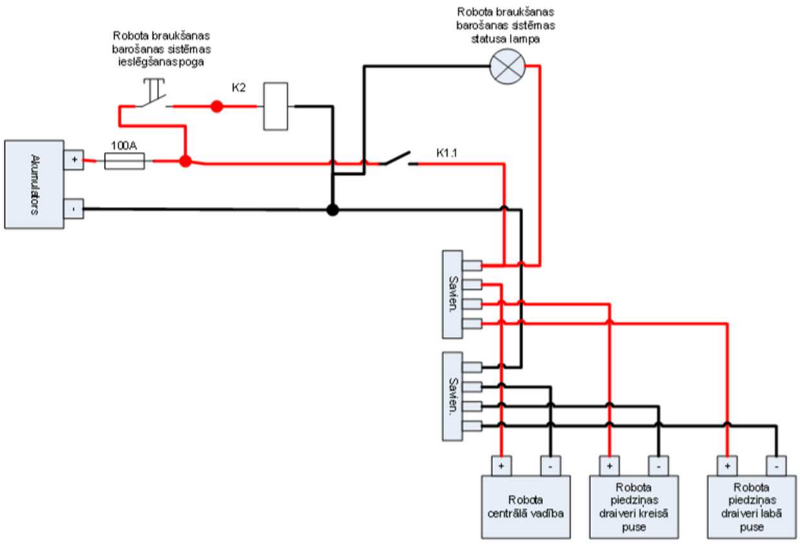
Robota platformas elektrobarošanas sistēma

Robota elementu enerģijas avots ir akumulatori. Robotā tiek izmantota industrijā plaši izmantota nomināli 24V DC zemsprieguma barošanas sistēma. Uz robota izveidotas divu veidu atdalītās barošanas sistēmas ar ķīmiskajiem akumulatoriem LiFePO4. Viens no akumulatoru blokiem atbild par CNC vadību un augstā līmeņa vadības sistēmas enerģijas apgādi skatīt zemāk atrodamajā shēmā 26. attēlā.



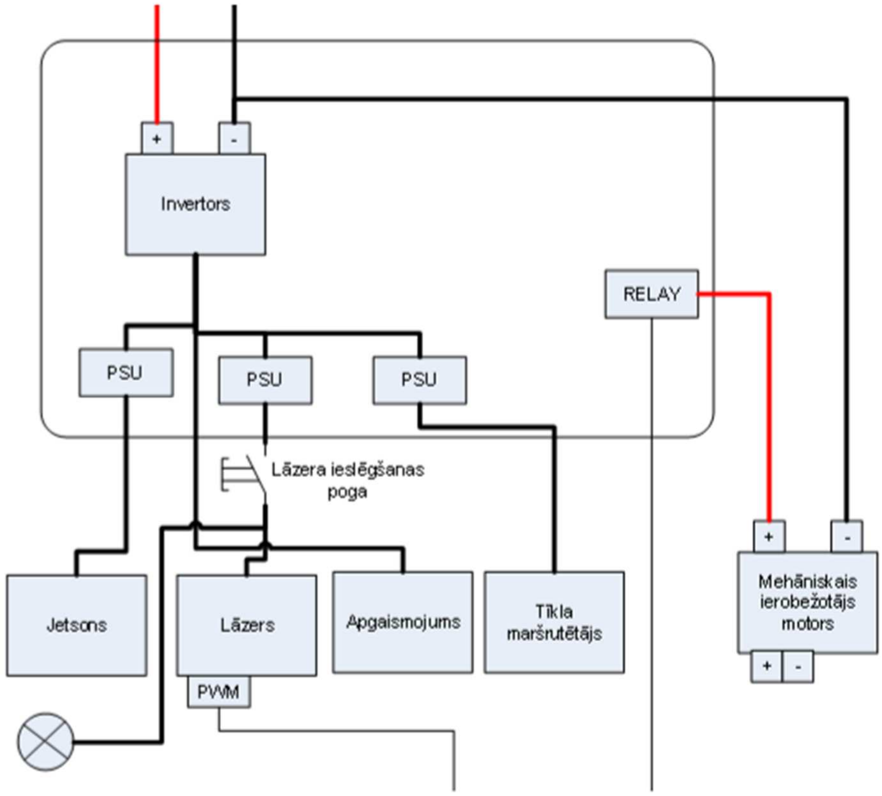
26. attēls Augsta līmeņa vadības enerģijas apgādes shēma

Enerģijas apgādes slēgumā iekļauta strāvas aizsardzība ar 100A drošinātāju. Papildus ar fiksējošo ieslēgšanas/izslēgšanas pogu vadot releju, ir iespēja atvienot elektrisko ķēdi, vadības elementiem. Kontrolei vai elektrobarošana ir ieslēgta vai izslēgta pievienota statusa lampa. Ritošās daļas nodrošināšanai ar elektroapgādi izmatots otrs akumulatoru bloks skatīt zemāk atrodamo shēmu 27.attēls.



27. attēls **Ritošās daļas elektroapgādes shēma.**

Lai nesabojātu akumulatorus, strāvas ķēdē ieslēgts 100A drošinātājs. Enerģijas pieslēgšanai un atslēgšanai no ritošās daļas elementiem un akumulatoru blokiem, tiek izmantots relejs. Ritošās daļas elementos iekļaujas robota divu pušu motoru bloku motori un robota centrālais vadības bloks. Austa līmeņa vadības elementos tiek iekļauts invertors, dators, lāzers, apgaismojums, tīkla maršrutizētāji un mehāniskais nezāļu ierobežotājs. Šo elementu slēguma shēmu var aplūkot zemāk redzamajā 28. attēlā.



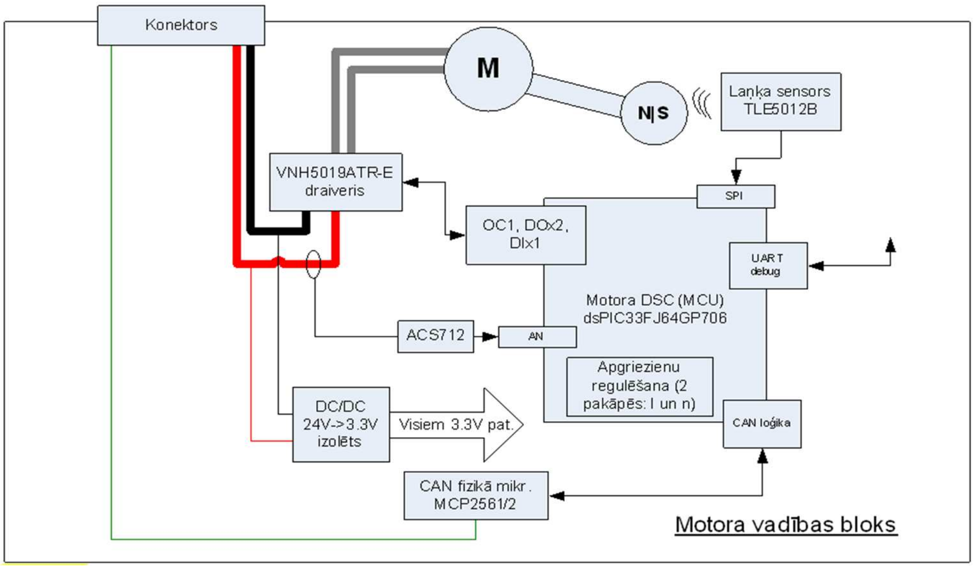
28. attēls Augsta līmeņa vadības elementu slēguma shēma

Robotizētās platformas piedziņas motoru vadība

LLU Tehniskās fakultātes rīcībā esošā lauksaimniecības robotizētā platforma piedziņai izmanto suku līdzstrāvas motorus ar atvērtas ķēdes impulsa platuma modulācijas vadību un bija oriģināli paredzēta vadībai tikai ar operatora pulti. Operators var vizuāli novērtēt robota gaitu un saķeres zušanas gadījumā uz vienas puses riteņiem iespējams manuāli pieregulēt padoto jaudu.

Projekta ietvaros ir nepieciešama precīzāka automātiska vadība, kas nodrošina riteņu rotāciju ar uzdoto ātrumu, kad augstāka līmeņa vadība, kas pieņem lēmumus par robota kustības traektoriju vagā vai starp darba/stāvvietas objektiem un var paļauties, ka kustība būs tāda, kāda ir uzdota piedziņas motoru vadības kontrolleriem. Lai to nodrošinātu, motoru vadības kontrolleri tika papildināti ar divām atgriezeniskām saitēm: strāvas sensoru un apgriezienu sensoru no riteņa. Strāvas sensors ir bezkontakta Holla tipa (mikroshēma ACHS-7123-000E) un magnetorezistīvais sensors (mikroshēma TLE5012B), kurš nosaka uz motora ass nostiprinātā magnēta leņķi, mēra leņķisko ātrumu un dod iespēju noteikt pašreizējos riteņa apgriezienus.

Programmā tika izveidoti abu sensoru interfeisi (analogciparu pārveidotājs strāvas sensora sprieguma izejai) un SPI interfeiss magnetorezistīvajam ass leņķa sensoram, kā arī pievienotas klāt PID vadības cilpas. Motora vadības bloka konceptuālā shēma dota 29. att.



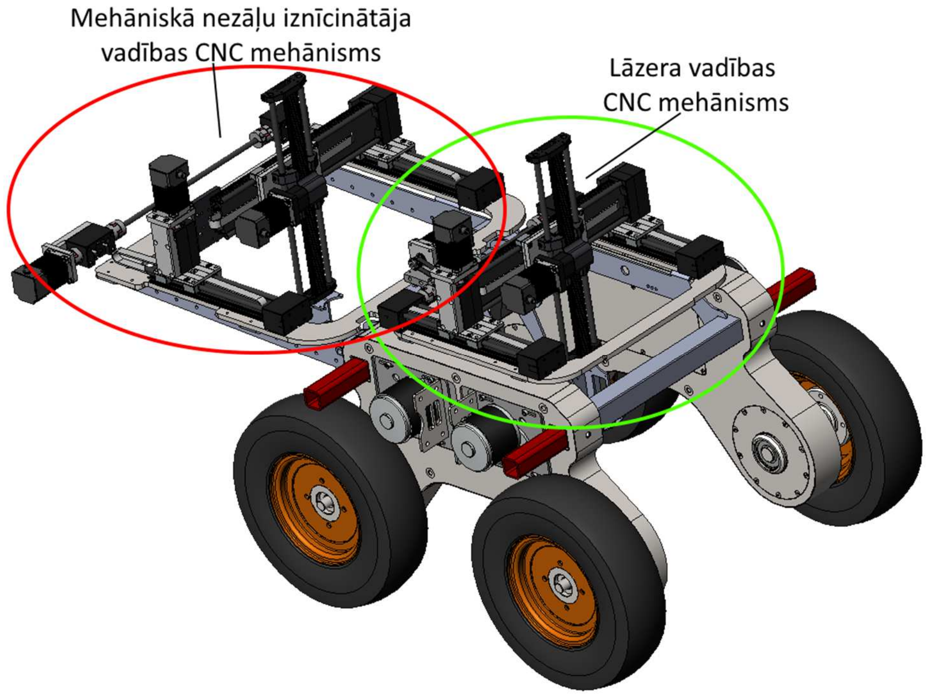
29. att. Motora vadības bloka konceptuālā shēma

1.3. Nezāļu ierobežošanas mehāniskais un lāzera agregāts

Nākamā svarīgā komponente, kas projektēta un uzstādīta uz robota platformas ir nezāļu ierobežošanas jeb iznīcināšanas izpildelementu vadības mehānismi. Nezāļu ierobežošanas mehāniskā agregāta un lāzera pozicionēšanai tika izvērtēti dažādi manipulatori: vairāku brīvības asu robotiskās rokas, *delta* robotiskās rokas, *scara* manipulatori un 3 asu mehānisms ar lineārām sliedēm un katraa kustīgā elementa neatkarīgu piedziņu (CNC). Lai arī citi manipulatori var sasniegt būtiski lielāku ātrumu (piem., scara robotiskās rokas), vai spēj veikt sarežģītākas kustības (piem., vairāku brīvības asu robotiskās rokas), CNC mehānisms tika izvēlēts, jo apvieno vairākas būtiskas īpašības:

- pieejama cena;
- putekļu un mitruma drošs;
- vienkārša mērogošana nākamajām robota versijām;
- pietiekoši liels sasniedzamais laukums.

Tā kā robota platformai projektā tika izvirzīta prasība nodrošināt nezāļu iznīcināšanu gan ar lāzeru, gan mehānisku izpildmehānismu, tad arī uz platformas tika ieprojektēti un uzstādīti divi neatkarīgi CNC mehānismi (skatīt attēlā).



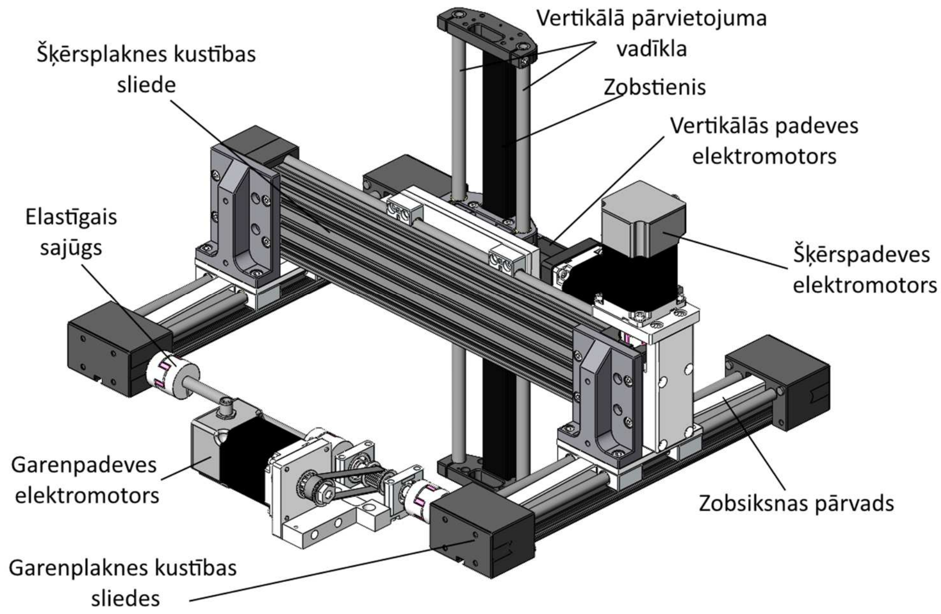
30. att. CNC mehānismu izvietojums uz platformas.

Konkrētās konfigurācijas CNC mehānismu izvēli iespaidoja sekojoši faktori:

- Nepieciešamais darba izpildmehānismu darbības laukums, kas katram nezāļu iznīcināšanas paņēmienam ir nedaudz atšķirīgs. Tā, kā ar lāzera iznīcinātāju paredzēts darboties tuvāk augam, tad šī mehānisma darbības laukums ir salīdzinoši mazāks par mehāniskā nezāļu iznīcinātāja darbības laukumu.
- Ierobežotā vieta starp robota sānu blokiem. Tā kā starpriteņu attālums ir noteikts un tas ir atkarīgs no vagu platuma, tad arī attālums starp dzenošajiem sānu blokiem ir ierobežots. Izvēloties CNC mehānismus bija nosacījums, ka to ārējiem gabarītiem jāiekļaujas noteiktos izmēros. Īpaši ierobežots laukums bija CNC mehānismam, kurš novietojas starp abiem sānu blokiem
- Potenciālie vagas un augu augstumi. Arī šis faktors nosaka to cik augstu būs jāuzstāda CNC mehānisms un cik lielam jābūt vertikālās ass pārvietojumam.

Konstruktīvi abi CNC mehānismi nostiprināti uz speciāli izveidotām biezsienu atbalsta plaknēm. Šādas atbalsta plaknes izveidotas, lai platformas pārvietošanās laikā pa nelīdzenu virsmu, nenotiktu CNC mehānisma šķiebšanās, kas varētu ietekmēt tā funkcionēšanu un arī resursu.

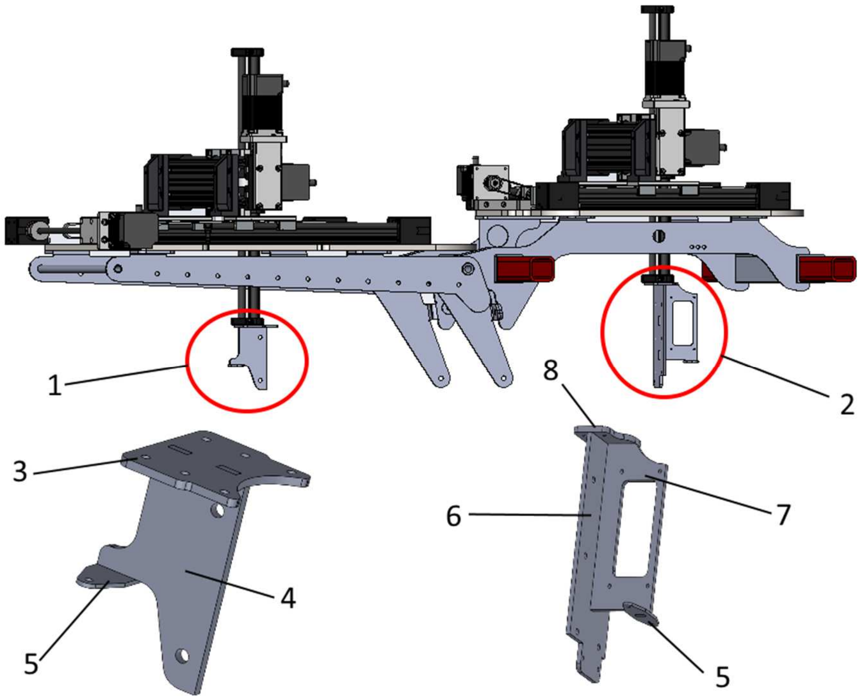
Abi CNC mehānismi precīzi sagregulēti un pieskrūvēti pie šīm atbalsta plaknēm, savukārt atbalsta plaknes pieskrūvētas pie speciāli izveidota CNC mehānisma rāmja sijas. Abu CNC mehānismu uzbūve un darbības principi ir līdzīgi, bet neliela atšķirība ir to gabarītizmēros un atsevišķu piedziņas motoru novietojumā. Lai iegūtu kompaktāku izmēru, lāzera darbināšanai paredzētā CNC mehānisma viens no soļu motoriem, nostiprināts pa vidu starp garenplaknes kustības sliedēm. Garenplaknes kustība abiem CNC mehānismiem tiek nodrošin ar divusliežu palīdzību katrā platformas pusē, turpretī, šķērsvirziena kustība tiek nodrošināta ar vienas sliedes palīdzību. Mehānisms slīdņu pārvietošanai tiek darbināts ar soļu motoriem un speciālām zobsiksnām. Savukārt vertikālā kustība tiek nodrošināta ar vertikāli izvietotu vadīklu palīdzību un piedziņu no soļu motora, kurš iedarbojas uz speciālu zobstieni.



31. att. CNC mehānisma konstrukcija

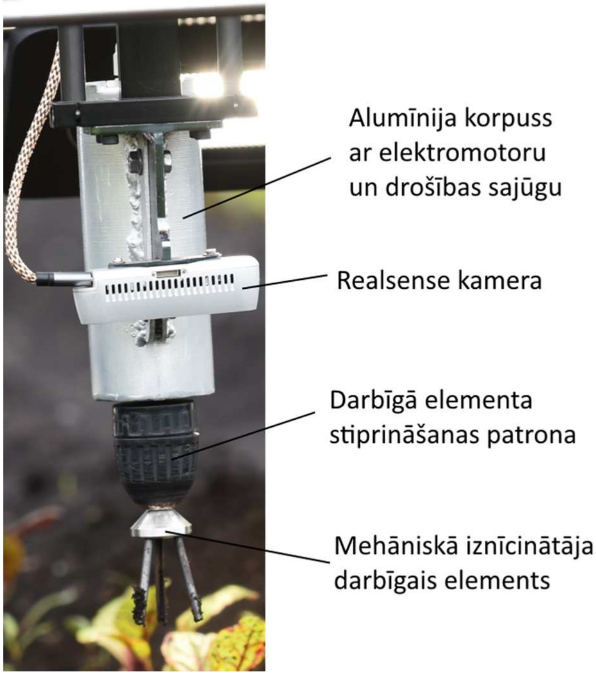
Nozīmīgs parametrs CNC mehānisma elementu izvēlē ir saistīts ar darba izpildmehānismu masu un paredzamajām slodzēm. Konstruktīvajam izveidojumam un soļu motoriem jābūt tādiem, kas ir spējīgi kustināt atbilstošas masas izpildmehānismus, turklāt jāierēķina arī inerces spēki, kas veidojas pārvietojuma gala stāvokļos.

Pie CNC mehānismu vertikālā pārvietojuma vadīklu apakšējiem kronšteiniem, tiek uzprojektēti un pieskrūvēti nezāļu iznīcināšanas izpildmehānismu stiprināšanas kronšteini. Katrs izpildmehānisms ir ar pilnīgi atšķirīgu konstrukciju, tāpēc arī stiprināšanas kronšteini ir atšķirīgi. Sekojošā attēlā parādīts gan mehāniskā nezāļu iznīcinātāja, gan arī lāzera mehānisma stiprināšanas kronšteins, turklāt abu kronšteinu konstrukcijas papildinātas ar speciāliem atlokiem Realsense kameru stiprināšanai. Šo kameru uzdevums ir nofotografēt apstrādājamo laukumu. Pēc uzņemtā attēla un speciāli izstrādāta algoritma vadības dators atpazīst kultūraugus un dod signālus CNC mehānismu un nezāļu iznīcināšanas mehānismu vadībai.



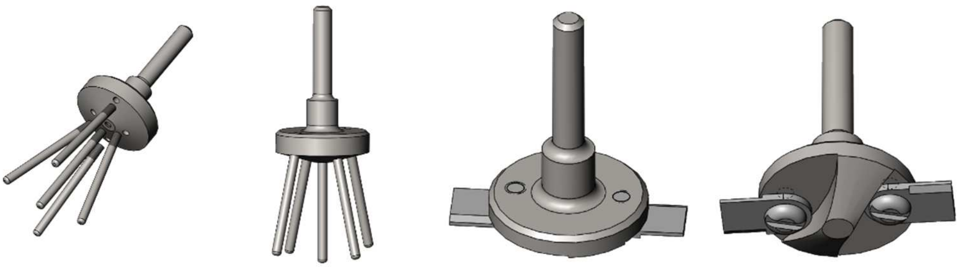
32. att. **Nezāļu iznīcināšanas darba ierīču stiprināšanas kronšteini**: 1. – mehāniskā nezāļu iznīcinātāja stiprināšanas kronšteins; 2 – Lāzermehānisma stiprināšanas kronšteins; 3. un 8. – Atloks stiprināšanai pie CNC mehānisma; 4 – mehāniskā nezāļu iznīcinātāja stiprināšanas atloks; 5. – Realsense kameras stiprināšanas atloks; 6 – Lāzera korpusa stiprināšanas atloks; 7 – Lāzera elektronikas bloka stiprināšanas kronšteins.

Nezāļu ierobežošanas mehāniskā agregāta pamatā ir mehānisks zaru irdinātājs/nogriezējs, kas tiek piedzīts no 12 V elektromotora. Lai iegūtu vajadzīgo griezes momentu, starp elektromotoru un darbīgo elementu ir uzstādīts kompakts reduktors, kurš samazina izejošās vārpstas apgriezienus, bet palielina griezes momentu. Darbīgais elements ir maināms un tas ir iestiprināms speciālā patronā. Lai netiktu bojāts elektromotors darbīgajam elementam saskaroties ar cietāku augsni vai akmeni, reduktora galā vēl ir uzstādīts drošības sajūgs, kas ļauj izslīdēt darbīgā elementa piedziņas patronai attiecībā pret elektromotora asi.



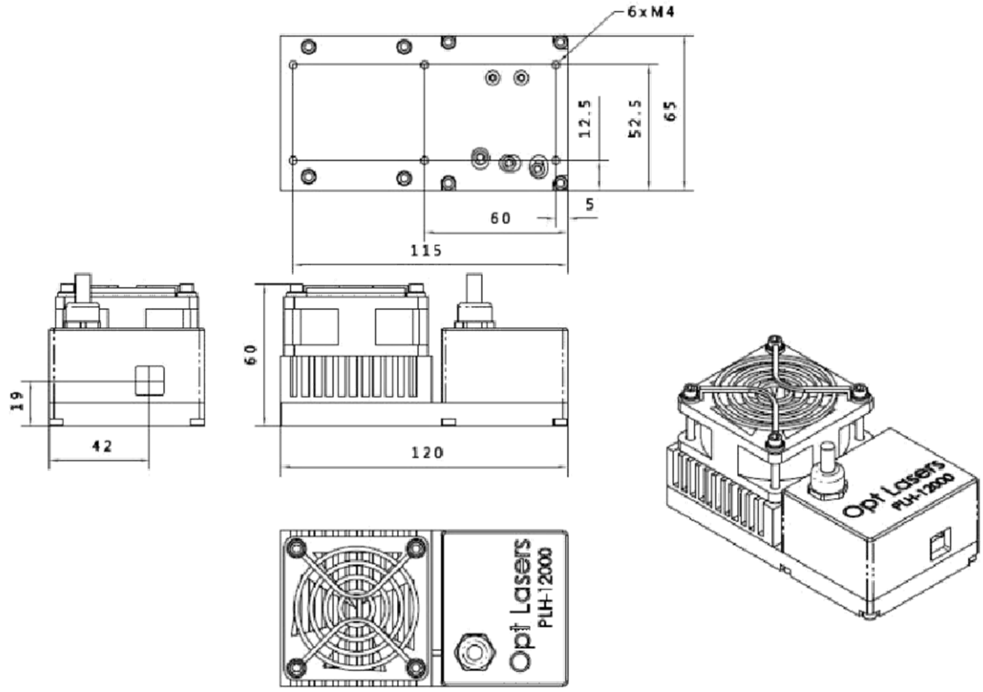
33. att. Mehāniskā nezāļu iznīcinātāja konstrukcija

Projektēšanas gaitā tika apskatīti un izstrādāti vairāki veidi nezāļu iznīcināšanas darbīgajām daļām. Tomēr par efektīvāko nezāļu iznīcināšanas darba elementu pie konkrēti izmantotā elektromotora apgriezieniem tika pieņemts darbīgais elements ar pīķveida zariem.



34. Att. Mehāniskā nezāļu iznīcinātāja darbīgo daļu varianti

Lāzera agregāta pamatā izmantots rūpnieciski ražots un tirgū pieejams OPT LASERS PLH-12000 lāzers, kas pielāgots un nostiprināts pie atbilstoši uzkonstruēta stiprinājuma kronšteina.



35. att. OPT LASERS PLH-12000 445nm lāzers

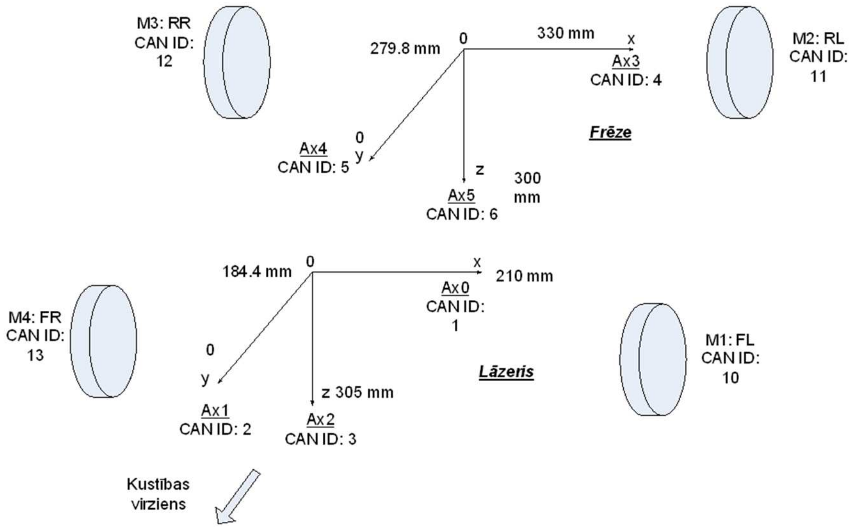
Protams, visu mehānisko komponenšu darbība un vadība nav iedomājama bez atbilstošas elektroinstalācijas un vadības programmu izstrādes. Elektroinstalācijas kabeļi un signālu vadi rasējumos nav parādīti. To izvietojums un montāžas vietas tiek izvēlēts pēc tam kad visas pamat komponentes ir samontētas.

Bez aukstāk minētajiem platformas elementiem pie platformas rāmja tiek pieskrūvēti arī apgaismes elementi, jeb LED prožektori, kas apgaismo apstrādājamo laukumu tā fotografēšanas brīdī. Konkrētai platformai izvēlēti 30 W prožektori. Pie tam apgaismes elementu izvēles īpatnība raksturojas ne tikai ar atbilstošas jaudas apgaismes ierīču izvēli, bet arī noteiktas LED vadības frekvences izvēli. Atšķirīgiem LED prožektoriem ir atšķirīga vadības frekvence, kas var ietekmēt neizgaismotu foto kadru efektu. Šāda parādība tika novērota, kad tika uzstādīti prožektori ar vadības frekvenci, kas neatbilda robota platformas Realsense kameru darbības frekvencei.

Iekārtas projektēšanas noslēgumā, tika izstrādāts iekārtas karkass, jeb pārklājs, kas paredzēts iekārtas darbīgo daļu aizsargāšanai no nelabvēlīgiem apkārtējās vides faktoriem, kā arī zināmā mērā tas kalpo kā daļējs drošības elements, kas pasargā apkārtējos no varbūtējas lāzera stara atstarošanos pret kādām atstarojošām virsmām.

Lineārās kustības asu motoru (CNC) kontrolleru integrēšana kopējā vadības programmā robota centrālajā platē

LLU Tehniskajā fakultātē esošā robotizētā platforma ir modulāra gan mehāniski, gan no programmatūras viedokļa. Modularitāte tiek nodrošināta ar unificēta CAN (Controller Area Network) tīkla palīdzību, kurš apvieno visu robota moduļu kontrollerus vienotā sistēmā vadībai no centrālās plates. Robota CAN tīklā tika integrētas arī komponentes, kas paredzētas lāzera un mehāniskā ierobežotāja pozicionēšanai: IGUS D1 soļu motoru vadības draiveri. Kopā pozicionēšanai tika izmantotas 6 asis (skat. 36. att.). Attēlā parādītas gan asu draiveru, gan piedziņas motoru CAN adreses.

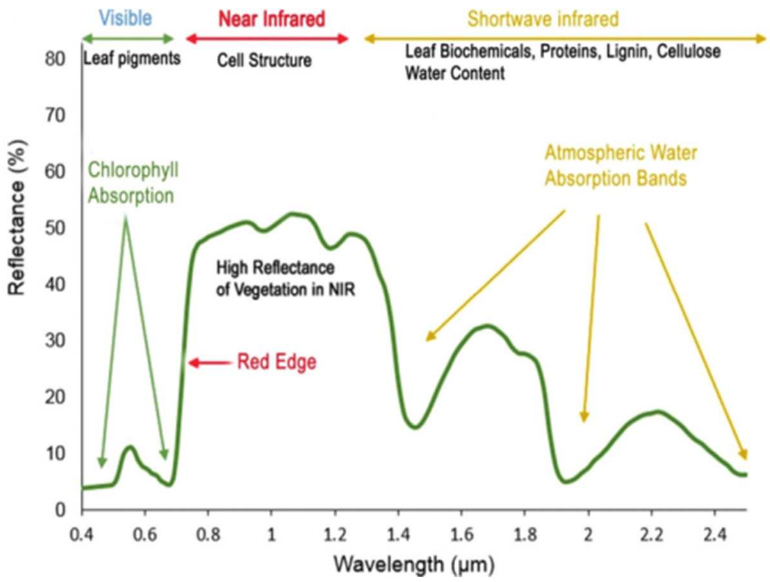


36. att. Robota CAN tīkla struktūra

1.4. Eksperimenti ar lāzera izmantošanu nezāļu ierobežošanai

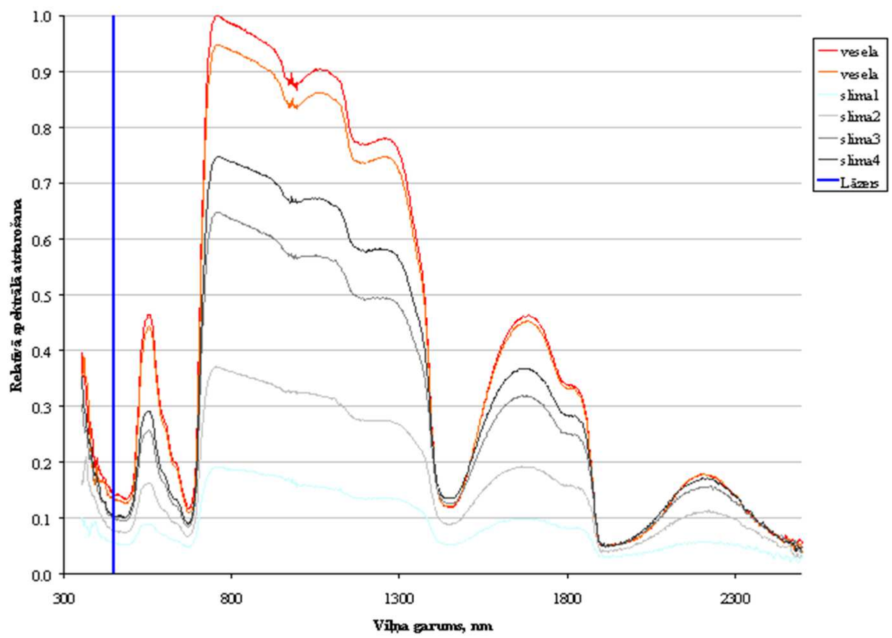
Lai izvēlētos nezāļu apstrādei piemērotākos lāzerus, tika veikta tirgū esošo lāzeru analīze, izvērtējot cenu, jaudu un potenciālo ietekmi uz augu. Augu zaļās daļas labi absorbē tikai atsevišķus elektromagnētiskā starojuma spektra joslas. 37., 38. att. parādītas spektrālās atstarošanas līknes veselām un bojātām augu lapām. Līkņu formu nosaka auga fizioloģija, nepieciešams starojums fotosintēzei hlorofilā, temperatūras regulēšanas nepieciešamība u.c. Ar nelielām atšķirībām šāds elektromagnētiskā starojuma atstarošanas profils ir praktiski visiem zaļajiem augiem. Tā kā lāzeri parasti darbojas šaurā spektra joslā (ar dažu nanometru izkliedi), tad ir nepieciešams izvēlēties tādu viļņa garumu, pie kura auga atstarošana ir pēc iespējas mazāka. Piemēram, zilajā, ultravioletajā vai īsviļņu līdz tālajā infrasarkanajā spektrā.

Pēc vispusīgas izpētes noskaidrots, ka no tirgū pieejamajiem risinājumiem tehniski un ekonomiski izdevīgākais ir pusvadītāju lāzers ar 445 nm viļņa garumu. Izvēli pamato starojuma labā absorbcija zaļajās augu daļās, kompaktie izmēri un masa attiecībā pret optiskā starojuma jaudu, viegla vadība, salīdzinoši augsta efektivitāte, lāzera sistēmas noturība pret vibrācijām un temperatūras izmaiņām un iespēja integrēt iekārtā, kurai jādarbojas lauka apstākļos.



37. att. Veģetācijas spektrālās atstarošanas līkne (Roman, Anamaria & Ursu, Tudor, 2016[1])

[1] Roman, Anamaria & Ursu, Tudor. (2016). Multispectral satellite imagery and airborne laser scanning techniques for the detection of archaeological vegetation marks.



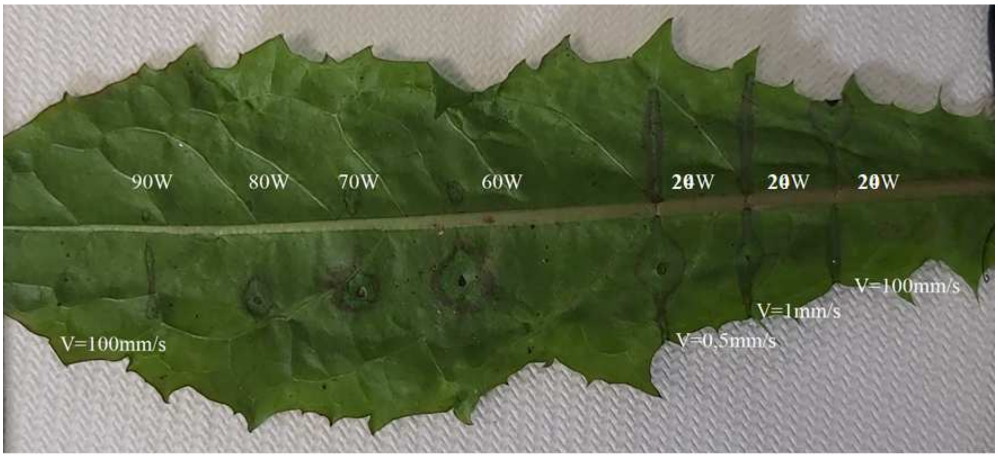
38. att. Relatīvās spektrālās atstarošanas līknes veselām un slimām augu lapām, uzņemtas LLU ar spektrometru "Spectral evolution RS3500". Ar zilu līniju parādīts izvēlētā pusvadītāju lāzera viļņa garums – 445 nm

Lai pārliecinātos par dažādu tehnoloģiju (pusvadītāju, šķiedras, CO_2) ģenerētā lāzera stara ietekmi uz augu zaļajām daļām reālos apstākļos, tika veikti praktiskie eksperimenti ar dažādu tehnoloģiju un viļņa garuma lāzeriem, kuri bija pieejami pētījumu laikā (39.-42. att.).

Rezultātā apstiprinājās, ka augu elektromagnētiskā starojuma atstarošanas īpašībām ir būtiska nozīme, piemēram, 1064 mm šķiedras lāzers nespēja atstāt būtisku ietekmi uz zaļas lapas virsmas pat pie vairāku desmitu vatu optiskās jaudas.

39. att. Lapu apstrādes eksperiments ar ražotājs BODOR 150 W CO_2 lāzeri (10600 nm viļņa garums, 20% jauda)

40. att. Lapu apstrādes eksperiments ar CO_2 lāzeri
(10600 nm viļņa garums, dažādas jaudas)



41. att. Lapu apstrādes eksperiments ar šķiedras lāzeri
(1064 nm viļņa garums, dažādas jaudas)

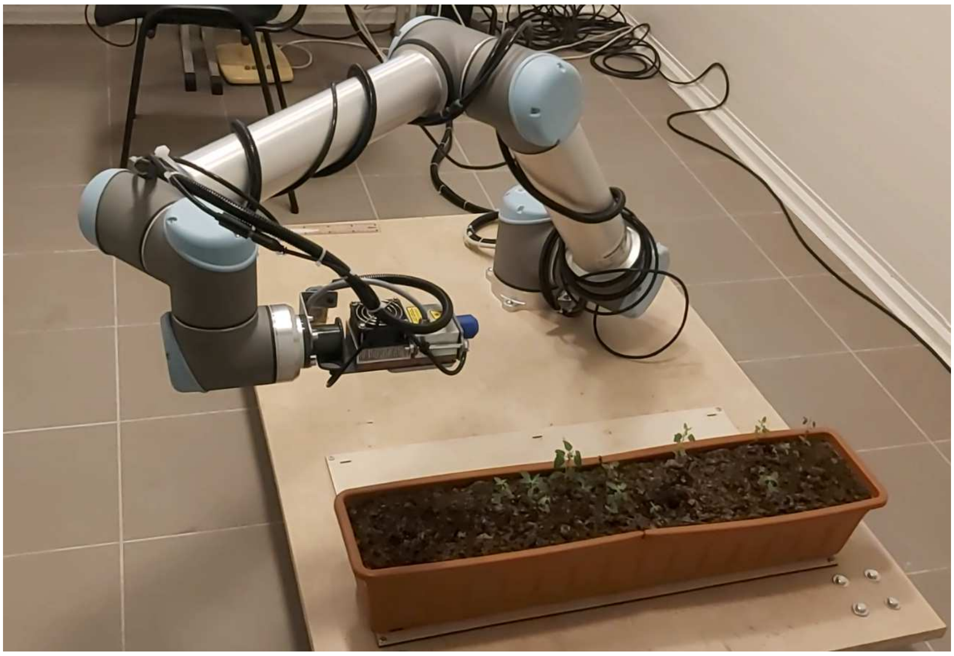
42. att. Lapu apstrādes eksperiments ar 30 W BIMEIGAO CO-A320 lāzergravētāju
(10600 nm viļņa garums, 50...100% jauda)

Balstoties uz eksperimentu rezultātiem tika nolemts robotam izmantot zilās gaismas lāzeru ar viļņu garumu 445-455nm.

Lāzera eksperimentu stends

Lai veiktu eksperimentus ar dažādiem lāzera parametriem – apstrādes ilgums, jauda, apstrādes laiks u.c. tika izveidots lāzera eksperimentu stends, lai kontrolētā un atkārtojamā veidā apstrādātu augus ar lāzera staru.

Par stenda pamatni kalpo 1256x880x22mm saplāksnis uz četriem pa Z asi savstarpēji neatkarīgiem riteņiem. LLU TF rīcībā esošais industriālais manipulators "UR10 Robot"[2] projekta laikā tika izmantots, lai imitētu robotizētās nezāļu ierobežošanas iekārtas manipulatoru darbību laboratorijas apstākļos. "UR10 Robot" tika piestiprināts pamatnei tā, lai pamatnes vienā pusē būtu vieta nezāļu stādu kastu novietošanai (skatīt 43. att.)



43. att. Lāzera eksperimentu stends.

Nezāļu ierobežošanas testiem tika izvēlēts PLH-12000 lāzera modulis[3]. Tas ir 445nm zilās gaismas pusvadītāja diodes lāzers ar 12W optisko jaudu. Detalizēts parametru apraksts atrodams 1. tabulā.

[2] https://www.universal-robots.com/products/ur10-robot/

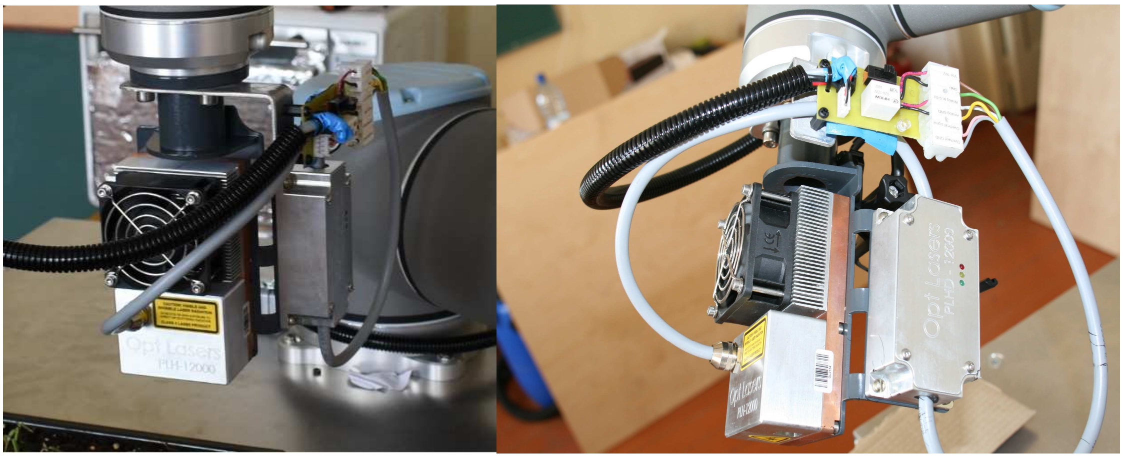
[3] https://optlasers.com/cnc-3d-lasers/plh-12000-engraving-laser-head

1. tabula.

PLH-12000 lāzera moduļa tehniskie parametri

Pusvadītāja diodes viļņa garums	445 nm
Lāzera moduļa masa	1,31 kg
Fokusēta punkta dimensijas 50mm attālumā no lāzera moduļa	0,15 x 0,4 mm
Lāzera moduļa vadības signāla sprieguma diapazons	0…5 V
Optiskais fokusa attālums	50 mm
Lāzera moduļa vadības modulācijas frekvence	100 kHz
Lāzera moduļa vadības modulācijas veids	analogs vai TTL
Optiskā jauda (pie darba vides temperatūras 20 °C)	12 W

Tika izgatavots speciāls kronšteins lāzera moduļa piestiprināšanai pie "UR10 Robots" manipulatora galvas (skatīt 44. att.).

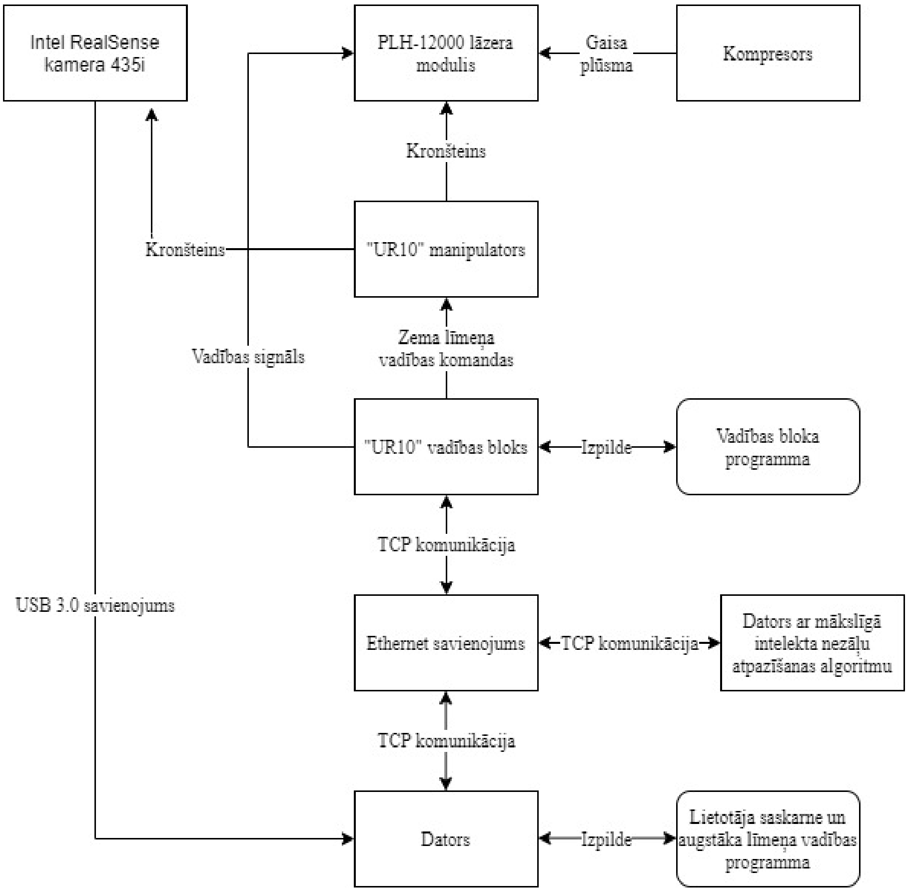


44. att. PLH-12000 lāzera modulis ar izstrādāto kronšteinu piestiprināts pie "UR10 Robot" manipulatora galvas.

Lāzera moduļa optisko elementu aizsardzībai no degšanas produktu nelabvēlīgās iedarbības tika izstrādāts gaisa sprausla, kura piestiprināta aiz lāzera moduļa stikla lodziņa. Sprauslai caur sānu pievadu pa lokanajiem pneimatiskām sistēmām paredzētiem gaisa vadiem tika pievadīts gaiss no kompresora, lai radītu gaisa plūsmu vērstu lāzera stara ass virzienā uz leju. Gaiss neļauj tvaikiem, dūmiem un citām nezāļu termiskās apstrādes procesā izveidotām daļiņām nokļūt uz lāzera moduļa stikla lodziņa. Ja uz stikla lodziņa nokļūst kāds svešķermenis, tad tas neizbēgami ar lāzera staru tiek sakarsēts, kā rezultātā sakarst arī pats stikls un rezultātā pārplīst, un iekārta kļūst nelietojama.

Projekta ietvaros tika veikti testi arī citiem lāzeriem. Kā perspektīvs variants lāzera jaudas blīvuma un cenas attiecībā tika izvēlēts PLH3D-6W-uSpot lāzera modulis. Šim lāzers var sasniegt ļoti augstu jaudas blīvumu - 680 kW/cm^2, bet tajā pat laikā lāzera punkta izmērs arī ir ļoti mazs.

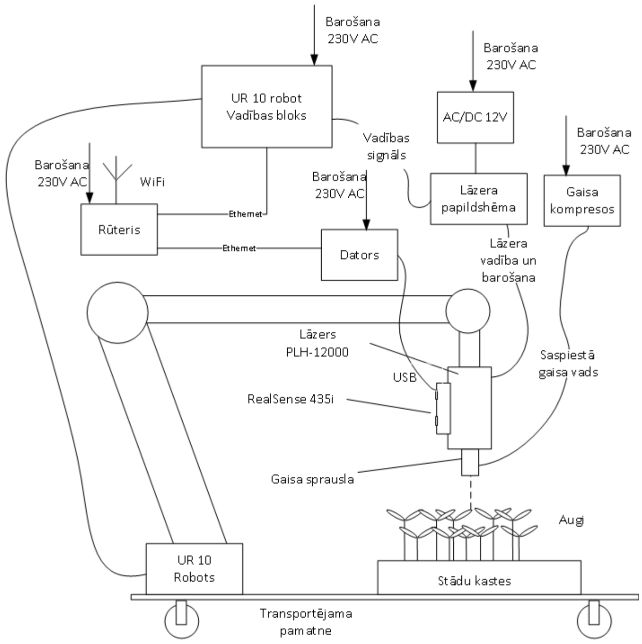
Manipulatoram ir savs centrālais vadības modulis, kurš izpilda zemā līmeņa komandas un nodrošina precīzu manipulatora pārvietošanos telpiskajās koordinātēs. Lai realizētu nezāļu ierobežošanas eksperimentiem nepieciešamās lāzera moduļa izejas stara kustības pa nezāļu lapas virsmām, tika izstrādāta augstāka līmeņa vadības programma ar lietotāja saskarni. Kopējā sistēmas uzbūve ir atspoguļota 45. attēlā.



45. att. Nezāļu ierobežošanas lāzera eksperimentu stenda uzbūves blokshēma

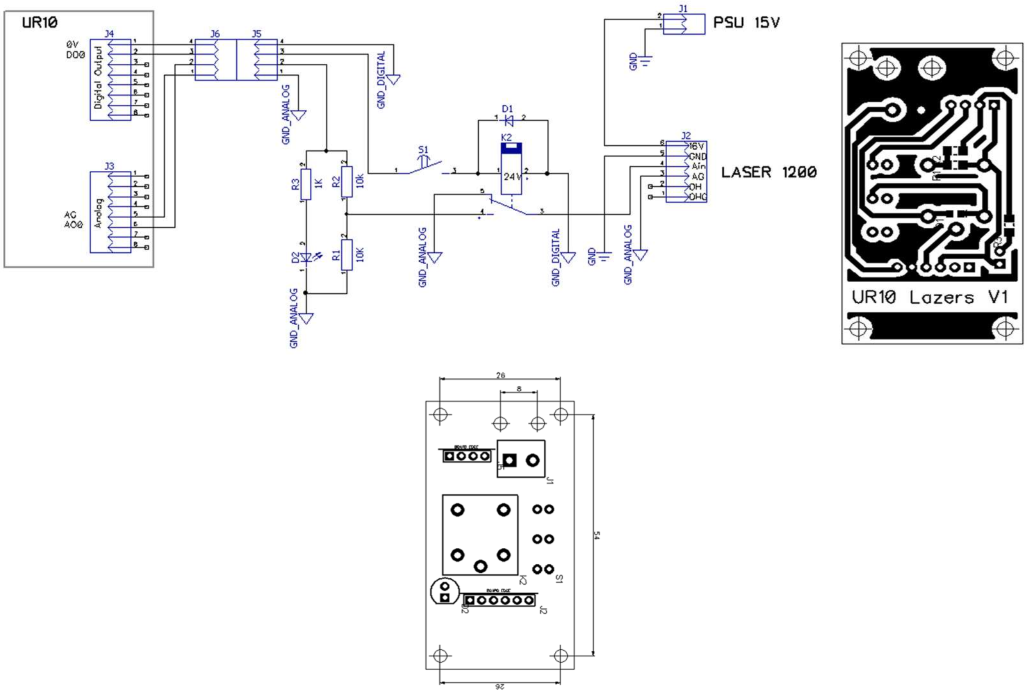
Manipulatora centrālais vadības bloks

Tika izstrādāta centrālā vadības bloka programmas, kuras galvenais uzdevums ir nodrošināt koordinētu manipulatora kustību un lāzera moduļa kontroli. Lāzera moduļa un vadības bloka slēguma shēma ir redzama 46. attēlā.



46. att. Robota rokas lāzera moduļa un vadības bloka slēguma shēma

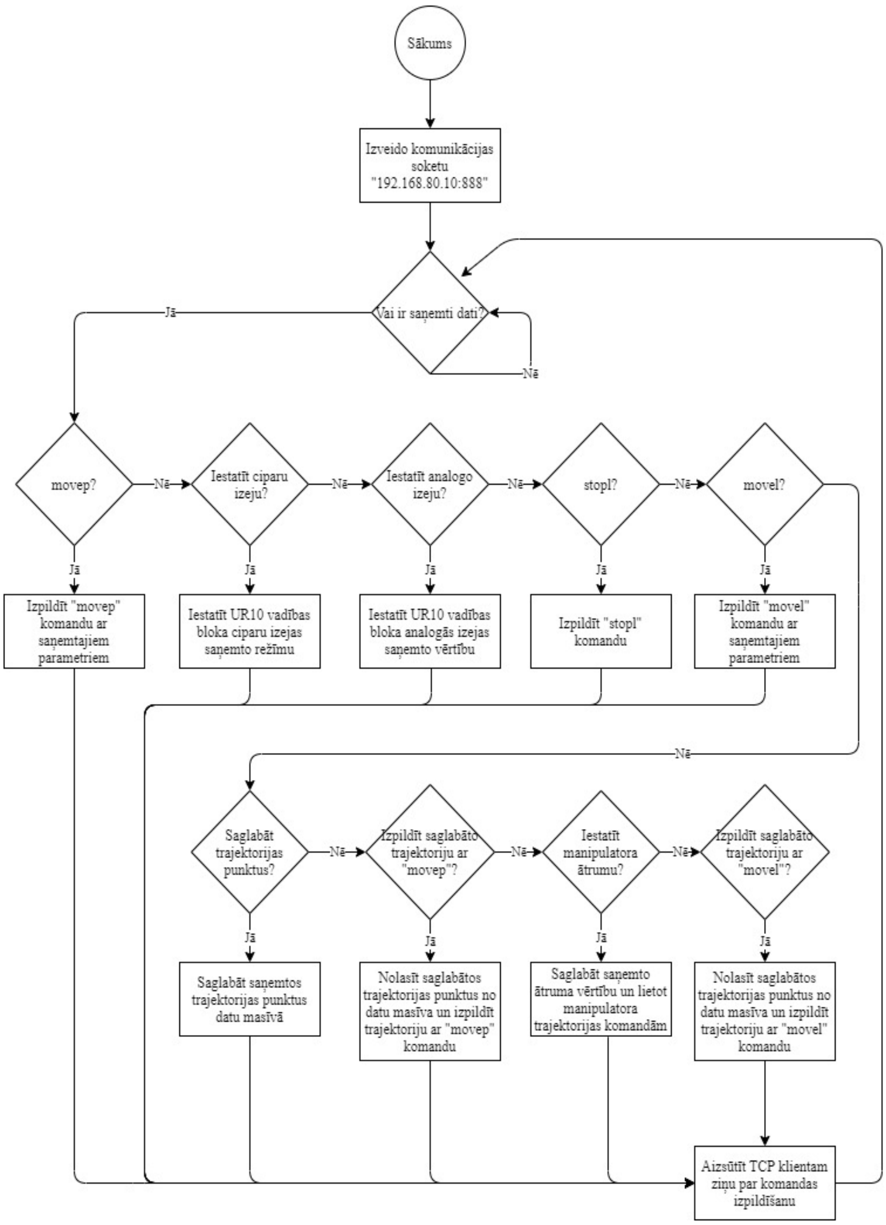
Centrālais "UR 10 robot" vadības bloks autonomi pēc ieprogrammētās programmas gaida komandas no vadības algoritma caur Ethernet (TCP). Šīs komandas satur robota rokas nākamās koordinātas un lāzera ieslēgšanās stāvokli. Lāzera vadībai tiek izmantots robota vadības bloka industriālie signāli. Viens no digitālajiem signāliem tiek lietots lāzera ieslēgšanas atļaujai. Otrs ir lāzera jaudas regulēšanas signāls. Robota vadības bloka signāla līmeņi ir standartizēti industrijā, bet lāzera ieejas signāli tam neatbilst. Lai risinātu šo situāciju, tika izveidota lāzera papildshēma, kura nodrošina salāgošanas iespēju un papildus tiek realizēta lāzera neieslēgšanas drošības slēgums. Shēma attēlota zemāk redzamajā 47. attēlā.



47. att. Lāzera papildshēma salāgošanai ar UR10 vadības bloku

Shēmā relejs paredzēts, lai izvairītos no nejaušas lāzera ieslēgšanās. No lāzera vadības signāls noklusēti ir uz releja normāli saslēgtajiem kontaktiem, kur ir sazemējums. No UR 10 vadības bloka tiek padots atļaujošais signāls uz K2 releju, kas liek relejam pārslēgties uz vadības analogo signālu. Lai izslēgtu nejaušu ieslēgšanos no UR10 robota puses, tad testu laikā izmanto fizisku releja spoles ķēdē ieslēgtu slēdzi S1. Ja slēdža kontakti nav savienoti, tad relejs nevar ieslēgties un padot uz lāzeri vadības signālu. Shēmā ir iestrādāts līmeņa pārveidotājs, kas nodrošina sprieguma dalījumu no UR 10 robota vadības bloka kas ir 0-10V DC uz lāzera ieejā pieļaujamo spriegumu 0-5V DC.

Vadības bloks tika nokonfigurēts tā, lai pēc vadības bloka ieslēgšanas tā operētājsistēma automātiski palaistu izstrādāto programmu. Programma mēģina pieslēgties augsta līmeņa vadības datorprogrammai un pēc veiksmīgas pieslēgšanās pāriet klausīšanās režīmā, lai uztvertu komandas. Manipulatora centrālās vadības bloka programmas darbības algoritms ir redzams 48. attēlā. Programmas kods ir atrodams 3. pielikumā.



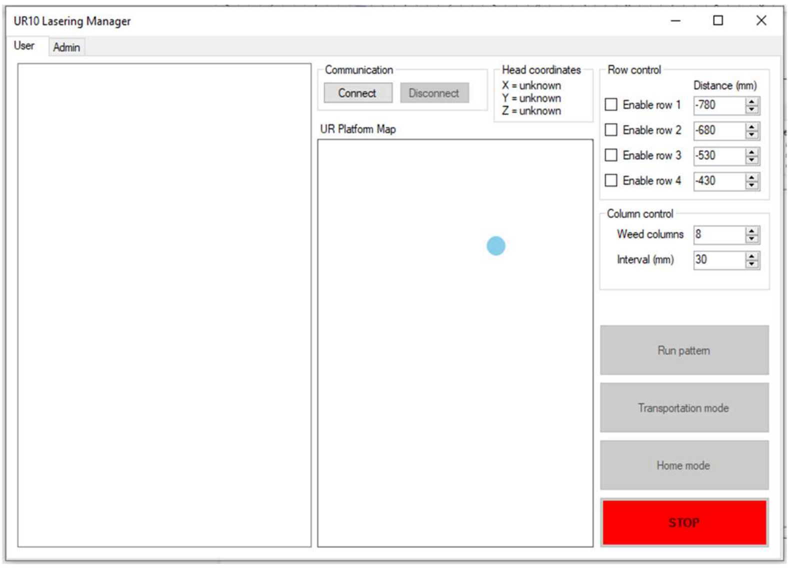
48. att. Manipulatora centrālā vadības bloka programmas blokshēma

Datorprogramma ar lietotāja saskarni

Augstāka līmeņa vadības datorprogramma ar lietotāja saskarni tika izstrādātā .Net ietvara C# programmēšanas valodā, kā "Windows Forms" lietotne. Programma nodrošina sekojošu funkcionalitāti:

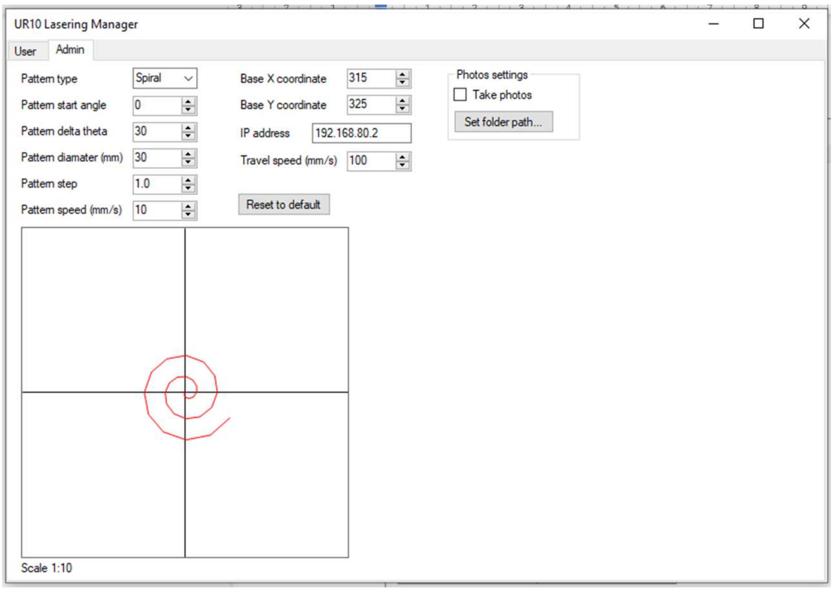
- komunikācija ar manipulatora centrālo vadības bloku,
- manipulatora inicializēšanas komandu nosūtīšana, pēc veiksmīgas TCP komunikācijas uzsākšanas,
- manipulatora galvas telpisko koordinātu nolasīšana un attēlošana grafiskajā saskarnē,
- komunikācija procesa attēlošana informācijas paziņojumu logā,
- manipulatora galvas kustības vizuāla attēlošana skatā no augšas,
- eksperimentu parametru iestatīšana,
- eksperimentu uzsākšana un apturēšana
- manipulatora iestatīšana "Atgriezties mājas" vai "Transportēšanas" režīmā

Lielākā daļa no minētajām funkcijām atrodas datorprogrammas galvenajā saskarnes logā (skatīt 49. att.). Saskarnē var pieslēgties vai atslēgties no manipulatora centrālā vadības bloka, redzēt TCP komunikācijas procesa ziņojumus, redzēt manipulatora galvas telpiskās koordinātas, manipulatora galvas kustības skatā no augšas eksperimenta laikā, iestatīt nezāļu stādu rindu un kolonnu skaitu un intervālus starp rindām, un intervālus starp kolonnām, uzsākt eksperimentu, ieslēgt manipulatora "Transportēšanas" režīmu, ieslēgt manipulatora "Atgriezties mājas" režīmu un veikt sistēmas avārijas apstāšanos. Saskarnes galvenā loga elementu izkārtojuma kods ir atrodams 4. pielikumā, savukārt vadības loģikas kods ir atrodams 5. Pielikumā.



49. att. Eksperimentu stenda datorprogrammas lietotāja saskarnes galvenais logs

Abpusējai TCP komunikācijas nodrošināšanai datorprogramma paralēlā CPU plūsmā iedarbina TCP serveri un gaida, kad manipulatora centrālais vadības bloks pieslēgsies. Pēc veiksmīgas komunikācijas nodibināšanas manipulatora centrālais vadības bloks tiek uzskatīts par TCP klientu, kuram datorprogramma sūta vadības komandas, un no kura saņem atbildes. Datorprogrammas komunikācijas izveidošanas kods ir atrodams 13. pielikumā un TCP kods ir atrodams 6. pielikumā. Pārējā funkcionalitāte (eksperimentu parametru iestatīšana) ir realizēta otrajā datorprogrammas lietotāja saskarnes logā. Lietotājs var izvēlēties: 1) lāzera iedarbības veidu jeb šablonu, 2) šablona parametrus (parametru veids atkarīgs no šablona veida), piemēram, diametru un soli, 3) šablona izpildes ātrumu (lāzera kustības ātrums eksperimenta laikā), 4) lāzera optisko jaudu un manipulatora kustības ātrumu, kad manipulators pārvietojās no "Mājas" pozīcijas uz nezāļu stādu atrašanās vietu un otrādi (skatīt 50. attēlu). Vēl ir iespējams ievadīt manipulatora centrālā vadības moduļa IP adresi un manipulatora bāzes grafiskās koordinātas attēlošanai galvenajā saskarnes logā. Saskarnes eksperimenta konfigurēšanas loga elementu izkārtojuma kods ir atrodams 4. pielikumā, savukārt vadības loģikas kods ir atrodams 5. Pielikumā.



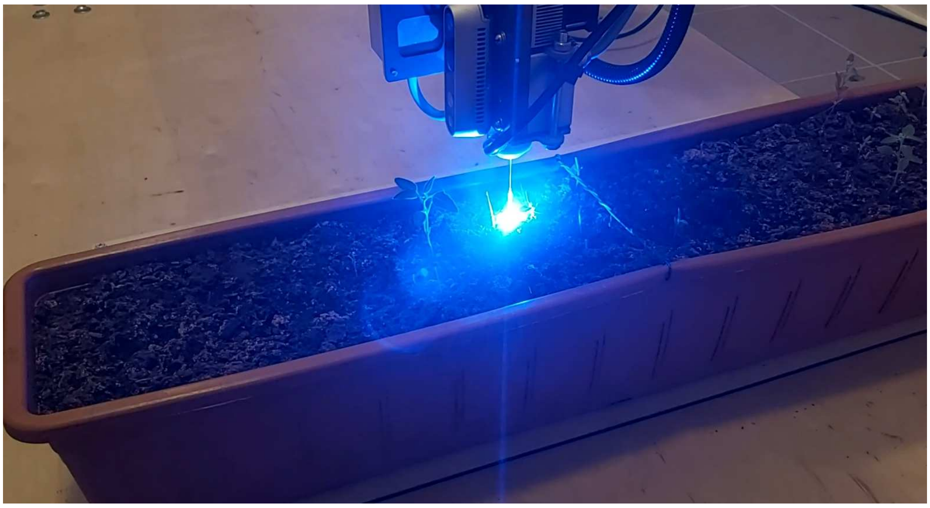
50. attēls. Eksperimentu stenda datorprogrammas lietotāja saskarnes konfigurāciju logs

Balstoties uz zinātniskās literatūras analīzi, tika pieņemts lēmums datorprogrammā realizēt divus lāzera iedarbības šablonus: zig-zag un spirāle. Viena eksperimenta ietvaros var izvēlēties vienu šablonu. Zig-zag šablona koordinātu punktu būvēšanas kods ir atrodams 7. pielikumā, savukārt spirāles šablona koordinātu punktu būvēšanas kods ir atrodams 8. pielikumā. Uzbūvēto šablonu koordinātu punktu izmantošanai datorprogrammā tika izstrādāts šablonu pārvaldnieks. Šablonu pārvaldnieks nodrošina šablona būvēšanas koda izpildi un iegūto koordinātu punktu nosūtīšanu uz manipulatora centrālo vadības bloku, kas savukārt nodrošina lāzera kustību pa nezāļu virsmu eksperimentu laikā. Šablonu pārvaldnieka kods ir atrodams 9. pielikumā.

Lai imitētu procesu no nezāļu atpazīšanas līdz iedarbībai ar lāzeru laboratorijas apstākļos, UR10 manipulatora galā papildus tika piestiprināta Intel RealSense 435i kamera[4]. Datorprogrammā tika izveidota speciāla procedūra manipulatora lineārām un rotācijas kustībām virs nezāļu stādu kastes, lai nodrošinātu fotoattēlu uzņemšanu ar kameras palīdzību (skatīt. 9. pielikumu). Uzņemtie fotoattēli tiek organizēti failu sistēmā un saglabāti norādītajā direktorijā (skatīt 14. pielikumu), kura pirms tam tika nokonfigurēta kā tīkla disks. Tīkla disks

[4] https://www.intelrealsense.com/depth-camera-d435i/

tika izveidots uz otra datora, kurā atradās mākslīgā intelekta nezāļu atpazīšanas algoritms (skatīt 45. att.). Datora algoritms gaidīja tīkla diskā jaunus attēlus. Tiklīdz attēli nonāca tīkla diskā, algoritms uzsāka nezāļu atpazīšanas procesu un rezultātu atgrieza teksta faila veidā. Datorprogramma interpretē teksta failā esošo rezultātu, aprēķina nezāles atrašanās vietu metriskajā koordinātu sistēmā un aktivizē nezāles termisko apstrādes procesu.



46. att. Lāzera eksperimentu stends darbībā – balandu apstrāde ar lāzeru

Eksperimenti augu pilna laukuma apstrādes pieeju novērtēšanai un metodika lāzera gaismas iedarbības uz augiem novērtēšanai laboratorijas apstākļos.

Nezāļu apstrādē ar lāzeru tika nolemts izmantot pilna laukuma apstrādes pieeju. Tā atšķiras no citu zinātnieku metodikas, kas ar lāzeru apstrādā atsevišķu jutīgu auga daļu, piemēram, meristēmas audus auga galotnē. Projekta pieeja balstās tajā, ka reālos apstākļos ir ļoti sarežģīti detektēt šo jutīgo punktu, jo nezāles ir vizuāli ļoti atšķirīgas ne tikai dēļ sugu dažādības un vizuāli atšķirīgajām attīstības stadijām, bet arī dēļ individuālajām deformācijām, augsnes īpatnībām, pašreizējā dabiskā starojuma, atmosfēras ietekmes (rasa, lietus pilieni), mehāniskajiem bojājumiem un savstarpējās pārklāšanās. Būtiskās atšķirība nezāļu vizuālajā izskatā apgrūtina mākslīgā intelekta attēlu atpazīšanas metožu izmantošanu atsevišķu augu identificēšanā, bet atsevišķu auga vasas daļu atpazīšana ir vēl papildus uzdevums.

Tāpat šādu uzdevumu apgrūtina potenciāla auga deformācija un/vai kustība telpā dēļ vēja vai arī tā apstrādes laikā, ja auga pārvietojums ir noticis laikā starp atpazīšanu un ierobežojošas iedarbes uzsākšanu.

Līdz ar to pilna auga virsmas apstrāde ar samazinātu lāzera optiskās enerģijas daudzumu praksē lauka apstākļos hipotētiski ir tehniski racionālāka, salīdzinot ar meristrēmu apstrādi ar lielas jaudas impulsiem. 47. att. parādīti eksperimentos augu apstrādes laikā izmantotie lāzera kustību (trajektoriju) modeļi: atsevišķu augu apstrādei un augu grupu apstrādei. Trajektoriju formas tika izvēlētas, lai atvieglotu UR-10 manipulatora kustības programmēšanu un panāktu maksimāli viendabīgu lāzera starojuma enerģijas sadalījumu uz apstrādājamo laukumu.

47. att. Augu apstrādes laikā izmantotie lāzera kustību modeļi: augšējā rinda no kreisās – atsevišķa auga spirāle, atsevišķa auga “zig-zag”, visa podiņa spirāle; apakšējā rinda – attiecīgie apstrādes rezultāti

Kā galvenais lāzera starojuma iedarbības raksturojošais lielums eksperimentos tika izvēlēts starojuma enerģijas daudzums uz laukuma vienību (džouli uz kvadrātmilimetru, J·mm^{-2}), kas tika izmantots arī citos radnieciskos zinātniskajā literatūrā publicētajos pētījumos. Lielums tika rēķināts, ņemot vērā pašreizējo lāzera jaudu, laiku, cik ilgi tiek pildīta dotā trajektorija virs apstrādājamā auga un apstrādāto laukumu.

Balstoties uz iepriekš apskatīto pieeju, tika veikts eksperiments, lai noskaidrotu dažādu kustības trajektoriju un apstrādes enerģiju ietekmi uz augiem. Tika veikti 3 testu tipi.

1. Tests dažādu apstrādes trajektoriju ietekmes noteikšanai. Tika izmantoti divi apstrādes trajektoriju veidi: spirālveida 10 mm diametrā, 8 vienmērīgi sadalītas cilpas un “zig-zag” formas trajektorija, kas aptver 10x10 mm kvadrātu, 6 līnijas. Lāzera kustības ātrumi tika izvēlēti tā, lai abos gadījumos viss modelis tiktu ievilkts aptuveni vienlaicīgi. Viena apstrāde uz vienu augu.
2. Tests, lai noteiktu iedarbības efektu uz vairākiem augiem vienlaikus. Visu veģetācijas podiņu apstrādāja, izmantojot ātrumu 30 mm·s^{-1} vai 90 mm·s^{-1}, savukārt visi pārējie parametri bija vienādi. Tika izmantots spirālveida trajektorijas veids ar kopējo diametru 60 mm un 24 cilpām, visi atsevišķi augi atradās tā iekšpusē. Viena apstrāde uz podiņu.
3. Tests lāzera enerģijas daudzuma noteikšanai uz atsevišķiem augiem. Atsevišķus augus apstrādāja, izmantojot 30 mm·s^{-1} vai 90 mm·s^{-1} ātrumu, kamēr visi pārējie parametri bija vienādi. Tika izmantots spirālveida raksts ar kopējo diametru 15 mm un 12 cilpām. Viena apstrāde uz vienu augu.

Kopsavilkums ar veiktajiem testiem dots 2. tabulā.

2. tabula

Veikto testu parametri lāzera starojuma ietekmes noteikšanas eksperimentā

Eksperimenta tips	Lāzera kustības ātrums, $mm \cdot s^{-1}$	Traektorijas diametrs vai sānu malas izmērs	Traektorijas laukums, mm^2	Apstrādes laiks, s	Kopējā enerģija, J	Enerģija uz garuma vienību, $J \cdot mm^{-1}$	Enerģija uz laukuma vienību, $J \cdot mm^{-2}$
1	22	10	100	6.04	72	0.60	0.725
1	20	10	79	5.88	71	0.59	0.898
2	30	60	2827	74.50	894	0.40	0.316
2	90	60	2827	25.28	303	0.13	0.107
3	30	15	177	9.12	109	0.38	0.619
3	90	15	177	3.38	41	0.14	0.229

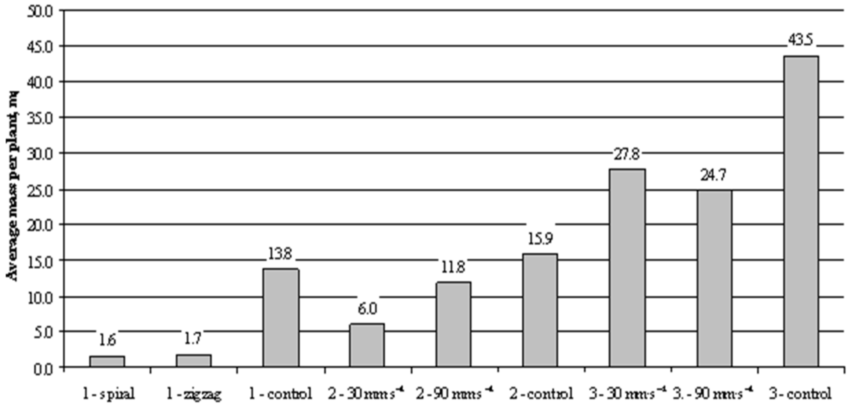
Eksperimentu rezultāti tika novērtēti pēc 7 dienām ar augu svēršanas metodi (svari – KERN ALJ 160-4AM). Rezultāti apkopoti 3. tabulā un 48. att.

3. tabula

Veikto testu rezultāti lāzera starojuma ietekmes noteikšanas eksperimentā

Testa grupa	Kopējā masa 7 d. pēc apstrādes, g	Augu skaits	Vidējā masa uz augu, mg
1 – spirāle	0.0147	9	1.6
1 – “zig-zag”	0.0154	9	1.7
1 – kontrole	0.2245	16	13.8
2 – 30 $mm \cdot s^{-1}$	0.2118	34	6.0
2 – 90 $mm \cdot s^{-1}$	0.4096	34	11.8
2 – kontrole	0.6054	38	15.9
3 – 30 $mm \cdot s^{-1}$	0.2499	9	27.8
3 – 90 $mm \cdot s^{-1}$	0.2225	9	24.7
3 – kontrole	0.7828	18	43.5

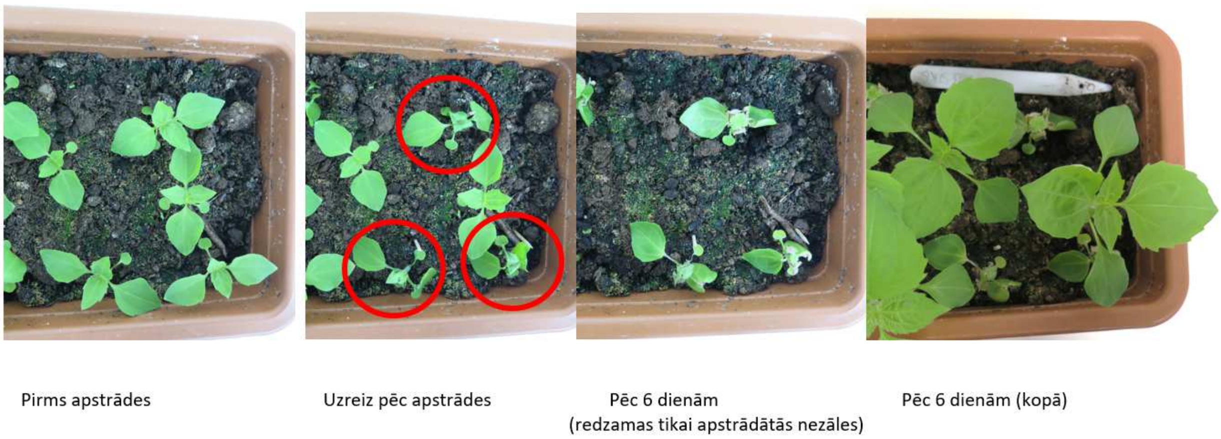
Lai gan šī eksperimentālie datiem netika veikta statistiskā apstrāde mazā augu skaita dēļ, ir skaidra tendence, ka piedāvātā laukuma lāzera apstrādes pieeja ierobežo nezāļu augšanu. Kā bija gaidīts, apstrādes laika un līdz ar to kopējās apstrādes enerģijas palielināšanās dod labāku rezultātu nezāļu augšanas ierobežošanā 1. un 2. eksperimentam. Vienīgais izņēmums ir 3. eksperiments, kur pēc 7 dienām pēc apstrādes veģetācijas ir nedaudz mazāka masa grupai apstrādāti ar zemāku enerģiju. To varētu izskaidrot ar zemu augu skaitu un sekojošu rezultātu svārstību pieaugumu.



48. att. Eksperimentā veikto testu rezultātu salīdzinājums

Rezultāti rāda, ka nezāļu apstrādei var efektīvi izmantot 445 nm (zilas krāsas) pusvadītāju lāzeru. Vislabākā energoefektivitāte ir apstrādes zonai, kas ir tuvu augu lapotnes lielumam. Apstrādes kustības traektorijas veids izrādījās nenozīmīgs. Eksperimentu metodika un rezultāti ir publicēti (Osadčuks et al, 2020).

Lāzera apstrādes rezultāts ir atkarīgs arī no auga morfoloģiskajām īpašībām – augiem ar biezākām lapām apstrāde jāveic ilgāk, lai augs saņemtu tikpat lielu enerģijas devu uz vienu masas vienību, kā mazāks augs. Līdzīgi ar auga attīstības stadijām – ja apstrādi veic dīgļlapu stadijā augu ir iespējams pilnībā iznīcināt. Kad tika veikta lielāku augu apstrāde, novērojām to, ka nezāles spēj veidot jaunas lapas un ataugt, tomēr to attīstība bija būtiski kavēta.



49. att. Sīkziedu sīkgalvīte pēc apstrādes ar lāzeru.

49. attēlā var uzskatāmi redzēt, ka augi, kas nav apstrādāti ar lāzeru ir turpinājuši augt, bet apstrādātās nezāles būtiski atpaliek savā attīstībā. Arī šāds efekts nezāļu kontrolē uz lauka varētu būt pietiekošs, jo tiek apturēta nezāļu augšana, bet kultūraugs tajā pašā laikā turpina augt, un labāk konkurē vai pat pāraug nezāli.

Eksperimenti enerģijas daudzuma uz laukuma vienību un apstrādes reižu skaita novērtēšanai

Citā eksperimentā tika precīzāk noteikts nepieciešamais enerģijas apjoms uz laukuma vienību augu apstrādē, kā arī pārbaudīta hipotēzi, ka var veikt vairākkārtēju apstrādi ar mazāku jaudu pretstatā vienai apstrādei ar lielāku jaudu. Eksperiments tika sadalīts 2 fāzēs: precīzāka nepieciešamā enerģijas daudzuma novērtēšana un atkārtojumu ietekmes noteikšana.

Lai novērtētu vairāku apstrādes reižu efektu un redzētu augu attīstības dinamiku, būtu nepieciešams svērt apstrādātos augus un kontroles grupu vairākkārtīgi, kas statistiskai apstrādei prasītu lielāku eksperimentālo objektu skaitu (kontrole un visas eksperimentālās grupas katrai svēršanas reizei). Uzdevuma atvieglošanai tika nolemts izmantot nedestruktīvu metodi – fotografēšana un attēlu apstrāde, kas ļauj novērtēt kopējo zaļo lapu apjomu. Šādai vajadzībai tika izveidots skritps "R statistics" vidē (15. pielikums).

Pirmās eksperimenta fāzes rezultāti doti 4. tabulā un 50. att.. Katrs augs individuāli tika apstrādāts ar spirālveida traektoriju 15 mm diametrā un soli < 2 mm. Tabulā aprēķināta uz augu nonākusī starojuma enerģija.

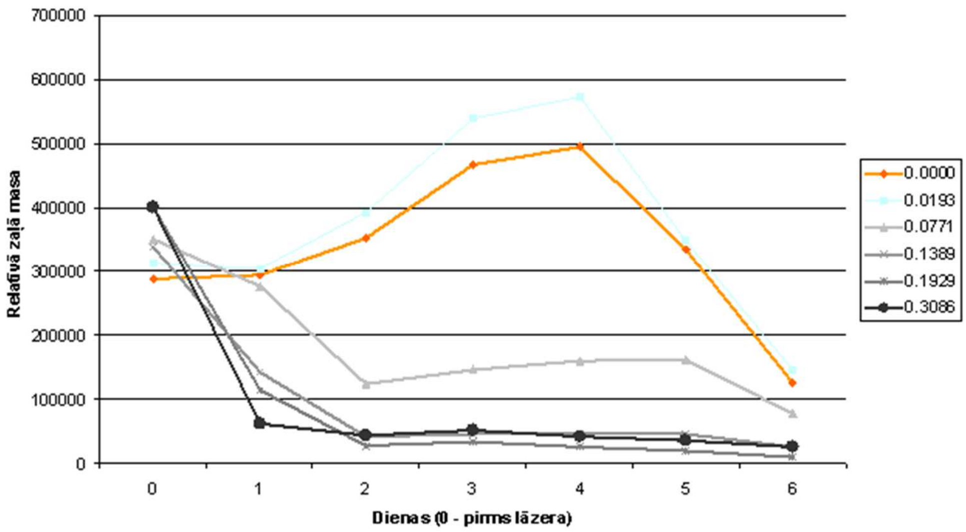
4. tabula

Veikto testu rezultāti precizētas lāzera starojuma ietekmes noteikšanas eksperimentā

ID	Jauda, %	J·mm^{-2}	Beigu masa, g
1	0	0	1.869
2	5	0.019285	2.08
4	20	0.077141	1.331
5	36	0.138854	0.753
6	50	0.192853	0.623
3	80	0.308565	0.668

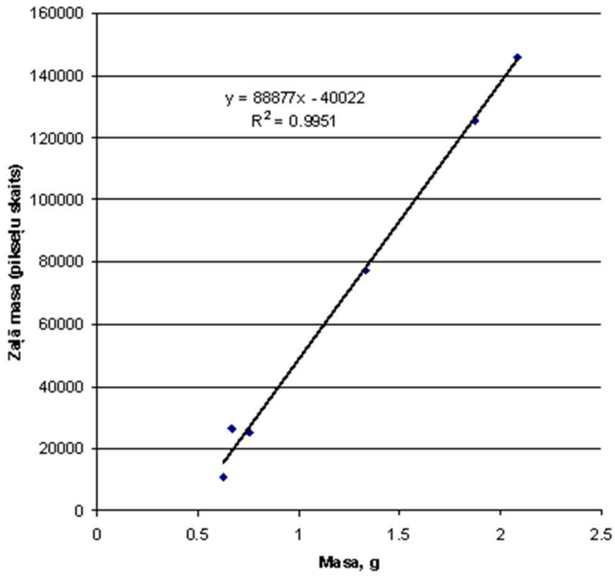
Grafiki pa dienām parāda zaļās masas (zaļo pikseļu skaita) dinamiku. 0. pozīcijā ir stāvoklis pirms lāzera apstrādes, 1, 2 utt. dienas numurs. 5. un 6. dienā augi netika laistīti, to var izteikti redzēt grafikos, tāpēc dati ir mazāk ticami. Džoulos doto mērījumu var izmantot, lai variētu ar lāzera jaudām un apstrādes ātrumiem turpmākajos eksperimentos.

Grafikos var uzskatāmi redzēt, ka vienreizējai 5% apstrādei nav ietekmes uz augiem. Grafiks parāda pat lielāku zaļo masu, kas izskaidrojams ar nelielā augu skaita radītajām statistiskajām svārstībām. Tāpat redzams, ka 36, 50, 80% apstrādes ietekmes savstarpēji būtiski neatšķiras, visos gadījumos rezultātā augi nav atkopušies eksperimenta perioda laikā. Beigu masa arī būtiski neatšķiras pie apstrādes jaudām 36% un vairāk.



50. att. Zaļās masas laukuma pieaugums (relatīvais laukums pikseļos) pa dienām. Līknes apzīmē dažādās apstrādes enerģijas, 0 – kontroles grupa

Papildus tika pārbaudīta korelācija starp svēršanas mērījumiem un zaļās masas laukuma pikseļu daudzumu (lapu laukumu). Grafikā (51. att.) var redzēt korelāciju starp pēdējo attēlu pikseļu rezultātu un svēršanu katrai eksperimenta grupai.



51. att. Korelācija starp attēlu zaļo pikseļu rezultātu un svēršanu katrai eksperimenta grupai

Galvenie secinājumi eksperimenta pirmajai fāzei.

1. Apstrādes enerģija 0.0193 J·mm^{-2} neatsāja būtisku ietekmi uz augiem pēc vienreizējās apstrādes
2. Apstrādes enerģija 0.0771 J·mm^{-2} uzreiz pēc apstrādes zaļās masas laukumu samazināja līdz 79% no sākotnējās, nākamajā dienā tā bija 35% mazāka nekā kontrole, bet pēc tam pakāpeniski turpināja pieaugt.
3. Enerģija 0.1389 J·mm^{-2} un vairāk pilnībā apturēja augu augšanu eksperimenta periodā.

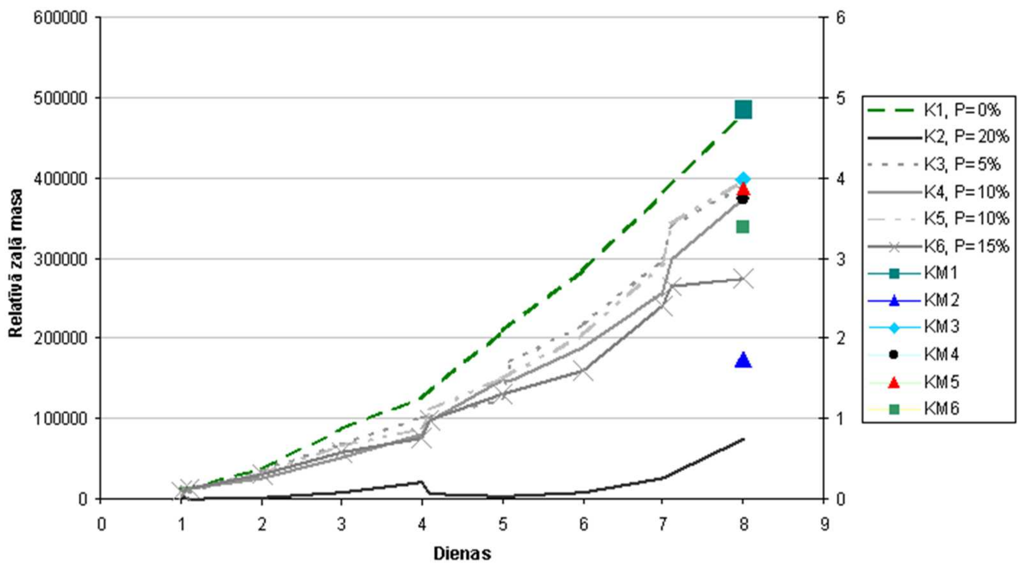
4. Zaļo pikseļu skaitīšana ir efektīva nedestruktīva metode augu attīstības dinamikas fiksēšanai. Par to liecina labā korelācija starp pikseļu skaitīšanas rezultātiem pēdējā uzņemtajā attēlā un augu masas mērījumiem.
5. Fotografēšanas metodika bija pieņemama – nepieciešami manuāli nemainīgi iestatījumi ar minimāliem lēcas kropļojumiem.

Otrajā eksperimenta fāzē augu apstrāde tika veikta ar atkārtojumiem. Arī otrajā fāzē katrs augs individuāli tika apstrādāts ar spirālveida traektoriju 15 mm diametrā un soli < 2 mm. 5. tabulā aprēķināta uz augu nonākusī starojuma enerģija, kā arī dota augu beigu masa un beigu laukums pikseļos. 52. att. parādīta augu zaļās masas dinamika.

5. tabula

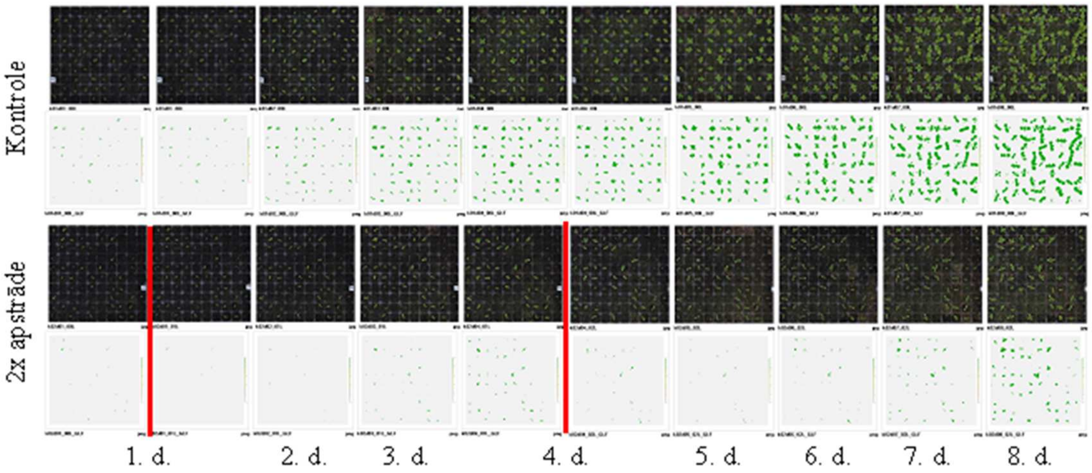
Eksperimenta otrās fāzes rezultāti augu apstrādē ar atkārtojumiem

Kastes ID	Jauda, %	Lāzera apstrādes atkārtojumi	Enerģija, J·mm^{-2}	Beigu masa, g	Beigu zaļā masa (pikseļi)
1	0 (kontrole)	0	0	4.86	481154
2	20	2	0.077141	1.7486	74992
3	5	5	0.019285	3.9807	390778
4	10	5	0.038571	3.7482	374538
5	10	3	0.038571	3.866	396529
6	15	3	0.057856	3.3898	273565



52. att. Relatīvās zaļās masas laukuma izmaiņas (līnijas) un beigu masas 8. dienā (simboli)

Grafikā lūzuma punktos var redzēt augu apstrāde atkārtojumus: 4. dienā kastēm 2-6, 5. dienā kastēm 3, 4 un 7. dienā kastēm 3-6. Vizuāli augu attīstība eksperimenta gaitā 2. grupai ar diviem atkārtojumiem parādīta 53. att.



53. att. Augu attīstība eksperimenta gaitā pa dienām, ar sarkanajām līnijām parādīti apstrādes brīži 1. un 4. dienā.

Eksperimenta otrās fāzes laikā noskaidrots, ka vairākkārtējā apstrāde ir vēlama jebkurā gadījumā, jo augiem ar attīstītu sakņu sistēmu, ir tendence atjaunot lapas pēc apstrādes. Tomēr apstrādes enerģijai ir jābūt pietiekošai, lai ietekmētu lapas: enerģijas zem 0.077 $J \cdot mm^{-2}$ līmeņa, nedeva vēlamo augu attīstības kavēšanas rezultātu pat pie vairākām apstrādēm.

Multispektrālās kameras izmantošana augu atpazīšanā

Visu iespējamo nezāļu sugu un augšanas stadiju atpazīšana, pielietojot mākslīgo intelektu, ir sarežģīts uzdevums gan funkcionāli (nepieciešamas apjomīgas apmācības kopas), gan veiktspējas ziņā (neironu tīklam atpazīšanas procesā jādarbojas vienlaicīgi ar daudzām klasēm). Tāpat papildus var rasties grūtības ar deformēto augu atpazīšanu. Deformācijas avoti var būt visdažādākie: slimību, dzīvnieku, atmosfēras iedarbības radītie bojājumi, kā arī pašas nezāļu ierobežošanas iekārtas darbības rezultāts, piemēram, ja nezāle ir daļēji ataugusi pēc pirmreizējās apstrādes ar lāzeri vai mehānisko ierobežotāju. Līdz ar to ir pamatota nepieciešamība izpētīt papildus metodes nezāļu identifikācijai uzņemtajos attēlos.

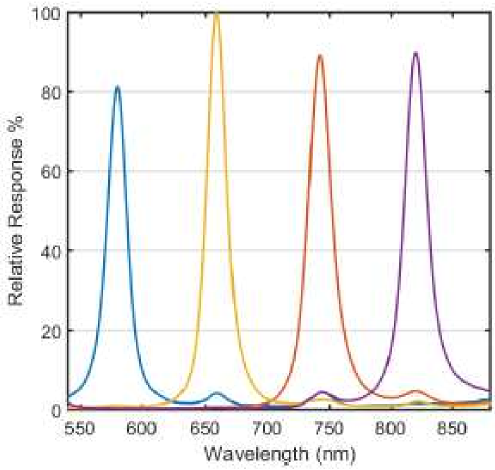
Viena no potenciāli izmantojamajām metodēm ir augu redzamā diapazona krāsu indeksi (RGB), kuri projekta ietvaros tika izmantoti lāzera iedarbības kvantitatīvai novērtēšanai (skat. 1.4. nodaļu). Attēlā uzņemto augu (tajā skaitā arī neatpazīto) zaļās daļas tiek identificētas, analizējot atsevišķu pikseļu vērtības un piemērojot minimālā laukuma filtru, lai izskaustu atsevišķu pikseļu un pikseļu grupu radītos traucējumus. Šīs metodes galvenais trūkums ir nepieciešamība pēc vienmērīga, nemainīga spektra apgaismojuma, kā arī nedrīkst būt atstarojumi no lapām. Laboratorijas apstākļos to var panākt, taču reālos lauka apstākļos tā ir būtiska problēma.

Par drošāku metodi dzīvu augu klātesamības noteikšanai var uzskatīt NDVI (*Normalized Difference Vegetation Index*) indikators jeb indekss, kuru katram attēla pikselim aprēķina pēc formulas:

$$NDVI = \frac{NIR - R}{NIR + R}$$

kur R – pikseļa sarkanā komponente

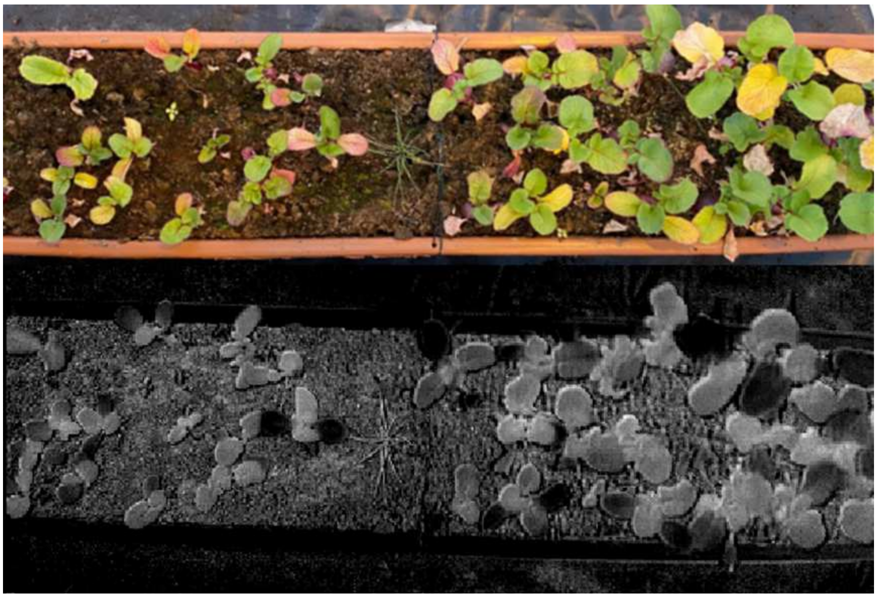
NIR – pikseļa tuvā infrasarkanā komponente (750-1100 nm).



54. att. Spectral Devices MSC-AGRI-1-A krāsu darba diapazoni
(avots: spectraldevices.com/sites/default/files/productsheets/mscam_agri_productsheet_ver06.pdf)

Šī metode tiek plaši pielietota jau vairākus gadu desmitus aerofotgrāfijā un satelītfotogrāfijā augkopības efektivitātes novērtēšanai. Indikators tiek pamatots ar auga spēju atstarot infrasarkano siltuma starojumu ar mērķi regulēt lapu temperatūru. Pārējie objekti, kas var nokļūt redzes laukā (augsne, smiltis, akmeņi, mirušas augu daļas u.c.) šajā spektrā atstaro relatīvi mazāk.

Projekta ietavors NDVI metode augu detektēšanas iespēju pārbaudei nezāļu ierobežojošā robota vajadzībām tika pielietota Spectral Devices MSC-AGRI-1-A multispektrālā kamera. Šī kamera darbojas redzamajā diapazonā, detektējot RGB krāsu komponentes, kā arī augu NIR atstarošanas maksimumā: 820 nm (skat. 54. att.).



55. att. RGB un NDVI attēls stresa apstākļos augošiem redīsiem

55. att. var redzēt NIR fotogrāfijas piemērus dažādām augu sugām dažādos veselības stāvokļos. Var uzskatāmi redzēt ka veselās lapas NDVI attēlos ir gaiši pelēkas, bet atmirstošās lapas – tumši pelēkas vai melnas.

NDVI fotogrāfijas var pielietot ne tikai, lai uzlabotu nezāļu detektēšanu, bet arī, lai paaugstinātu nezāļu ierobežošanas iekārtas ražīgumu, izlaižot apstrādē nezāles, kuru attīstība ir kavēta un kuri vairs nevar būtiski traucēt kultūrauga attīstību.

2. Vizuālo datu kopas sagatavošana un anotēšana nezāļu atpazīšanas algoritma apmācībai

Lai nodrošinātu nepieciešamos augu attēlus ar kuriem apmācīt augu atpazīšanas algoritmu, projektā iesaistītās zemnieku saimniecības veica kultūraugu audzēšanu. Projektā tika izvēlēti seši kultūraugi (parastā biete (*Beta vulgaris*), sējas burkāns (*Daucus carota var. sativus*), cukini (*Cucurbita pepo* subsp. *pepo*), parastais ķirbis (*Cucurbita pepo*), dārza redīss (*Raphanus sativus var. sativus*), melnais rutks (*Raphanus sativus var. niger*). Kultūraugi tika audzēti atklātā laukā atbilstoši saimniecībā izmantotajai tehnoloģijai.

Saimniecības veica nepieciešamos augsnes sagatavošanas darbus, kultūraugu sēju un vajadzības gadījumā arī nezāļu mehānisku kontroli, lai tās neizaugtu pārāk lielas un neaizklātu kultūraugus. Kultūraugi tika sēti vairās reizes sezonā, lai nodrošinātu, ka visu sezonu ir pieejami augi agrās attīstības stadijās.

56. att. Saimniecības “Lejasvagaļu dārzs” ķirbju lauks

57. att. Saimniecības ZS “Atvases” biešu un burkānu lauks

58. att. J. Lipska saimniecības “Absolūts Ēd” redīsu un rutku lauks

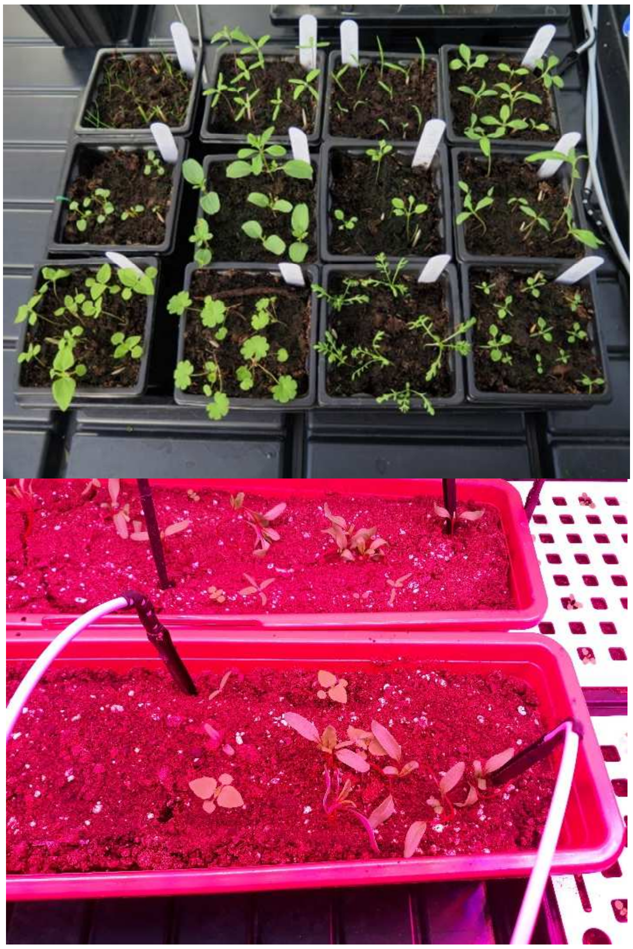
Papildus augu audzēšanai uz lauka, Agrihorta siltumnīcā tika audzēti gan kultūraugi, gan nezāles. Siltumnīcā audzēti augi tika izmantoti gan fotogrāfiju iegūšanai augu atpazīšanas algoritma apmācībai, gan eksperimentiem ar lāzera apstrādi. Augu audzēšana siltumnīcā ļāva nodrošināt pieeju augiem agrās attīstības stadijās visu gadu.

59. att. Kultūraugu un nezāļu audzēšana Agrihorta siltumnīcā

Augu fotografēšanu vica gan Agrihorta darbinieki, gan saimniecību pārstāvji ar šim nolūkam izgatavoto fotografēšanas aprīkojumu.

2.1. Augu audzēšana siltumnīcā

Agrihorta siltumnīcā kontrolētos apstākļos tikai veikta nezāļu un kultūraugu audzēšana. Lai noskaidrotu savvaļas augu audzēšanas iespējas siltumnīcā ziemas apstākļos tika iesēta 21 nezāļu suga (aklis (*Galeopsis spp.*), baltā balanda (*Chenopodium album*), baltā spulgotne (*Melandrium album*), dārza vējagriķis (*Polygonum convolvulus*), ganu plikstiņš (*Capsella bursa-pastoris*), gerānija (*Pelargonium spp.*), ķeraiņu madara (*Galium aparine*), lauka magone (*Papaver dubium*), lauka vijolīte (*Viola arvensis*), maura skarene (*Poa annua*), parastā gaiļsāre (*Echinochloa crusgalli*), parastā rudzusmilga (*Apera spica-venti*), parastā rudzupuķe (*Centaurea cyanus*), parastā virza (*Stellaria medium*), rudzu lāčauza (*Bromus secalinus*), sīkziedu sīkgalvīte (*Galinsoga parviflora*), tīruma gaurs (*Spergula arvensis*), tīruma kumelīte (*Matricaria inodora*), tīruma naudulis (*Thlaspi arvense*), tīruma radzene (*Cerastium arvense*), vējauza (*Avena fatua*)), kā arī piecas viendīgļlapju kultūraugu sugas (auzas (*Avena sativa*), vasaras kvieši (*Triticum aestivum*), vasaras mieži (*Hordeum vulgare*), ziemas kvieši (*Triticum aestivum*), ziemas rudzi (*Secale cereale*)). Augu audzēšana attēlota 60. attēlā.



60. att. Augu audzēšanas konteineri ar dažādiem augiem.

Nezāļu sugas tika audzētas gan atsevišķi, gan vairākas nezāļu sugas ar kultūraugu, tādā veidā imitējot apstākļus uz lauka. Augsnes sagatavošanai tika izmantots dzeramais ūdens un firmas kūdras substrāts ("Biolan", pH 6.0, elektrovadītspēja (EC) 25 mS m^{-1}, mitruma saturs <65%, kūdras frakcija <2.0 cm, N 12.0%, P_2O_5 14.0%, K_2O 24.0%, Te 1.0 kg m^{-3}). Katrā dēstu podiņā augu sēklas tika sētas ar neregulāru attālumu. Sēklu dīgšana dēstu podiņos ilga vidēji vienu līdz divas nedēļas. Dēstu podiņus pēc nepieciešamības aplaistīja vienu līdz divas reizes nedēļā. Augu laistīšanai dēstu podiņus novietoja uz specializētiem appludināmiem siltumnīcas galdiem. Tika novērots, ka starp nezāļu sugām būtiski atšķiras sēklu dīdzība kā arī daļa augu kavējās attīstībā.

Turpmākai audzēšanai tika izvēlētas dārzkopībā bieži sastopamas nezāļu sugas, kuras varēja veiksmīgi kultivēt siltumnīcā - baltā balanda, ķeraiņu madara, tīruma naudulis, ganu plikstiņš, sīkziedu sīkgalvīte, tīruma kumelīte. Augu audzēšanai tika izmantots kūdras substrāts, kam pievienoja granulētu komplekso mēslojumu "Yara Complex" 20 g m^{-2}, kura sastāvā ir N 12.0%, N – NH_4 7%, N – NO_3 5%, P_2O_5 11%, K_2O 18%, Mg 1.6%, S 8%, B 0.015%, Fe 0.2%, Mn 0.02%, Zn 0.02%. Augu sēklas viena no otras dēstu kastēs tika iesētas ar neregulārām atstarpēm, un divās līdz trijās kolonnās ar 2.0 – 5.0 cm atstarpēm. Sēklu dīgšana dēstu kastēs ilga vidēji vienu līdz divas nedēļas.

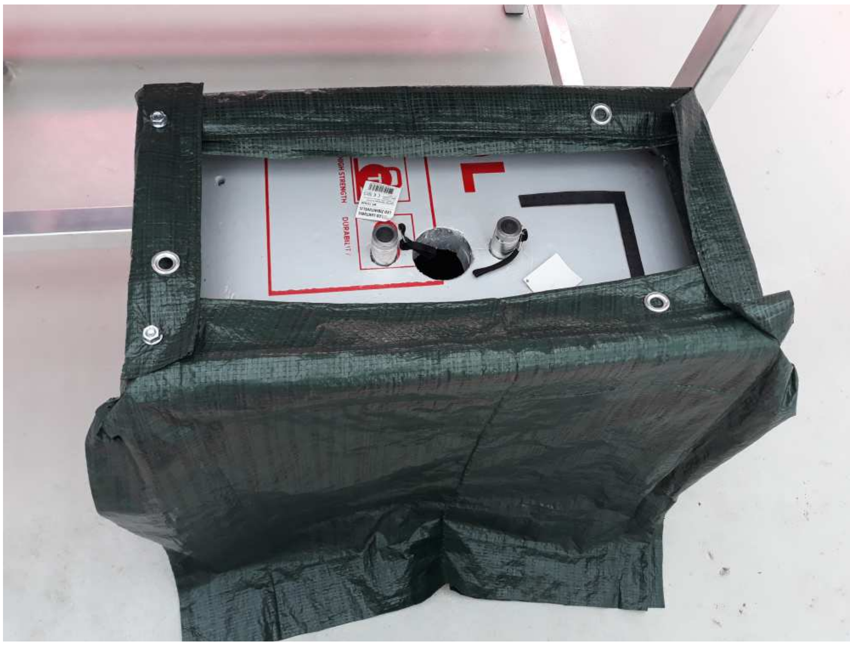
Gadījumos, kad dēstu kastes ilgstošā laika periodā laistīja no augšas, tika novērota aļģu savairošanās uz substrāta virskārtas. Aļģes traucē izmantot zaļo pikseļu noteikšanas algoritmus, jo gan fons, gan augs ir zaļā krāsā. Pēc šī efekta konstatēšanas tika mainīta laistīšanas metode – laistīšanu no augšas aizvietojot ar galdu uzpludināšanu.

61. att. Aļģu kārtu uz kūdras substrāta

Augus dēstu podiņos un kastēs audzēja Agrihorta siltumnīcā kontrolētos apstākļos. Augu attīstībai nodrošināja +20.0 C° temperatūru no plkst. 8:00 – 20:00, bet nakts laikā no plkst. 20:00 – 8:00 +15.0 C° temperatūru. Vidējais gaisa mitruma saturs visā augu attīstības periodā bija 50%. Papildu saules gaismai, augu audzēšanai tika izmantota LED apgaismojuma lampas (Philips Lightning IBRS, 400V AC Nom 180W, IP66) un nātrija lampas ar apgaismojuma periodu no plkst. 06:00 – 20:00. Ziemas mēnešos (novembris – februāris) siltumnīcā audzētiem augiem novērota pasliktināta sēklu dīgšana un attīstība.

2.2. Fotografēšanas aprīkojums

Dēstu podiņu fotografēšanas stends. Augu, kas atradās dēstu podiņos, fotografēšanai siltumnīcā, tika konstruēts rāmis ar platformu un perpendikulāri regulējamu augstumu pret plakni, un uzstādītu mākslīgo apgaismojumu. Konstrukcijas – rāmja izgatavošanai izmantoja metāla stūra profilus (platums 2.5*2.5 cm) un metāla skrūves ar uzgriežņiem. Rāmi no malām aizsedza ar melnu, gaismas necaurlaidīgu polietilēna plēvi (biezums 0.2 mm). Polietilēna plēve nodrošināja aizsardzību no citiem gaismas avotiem (piemēram, saules apgaismojums). Platformai izmantoja putu polistirola loksni. Polistirola loksni montēja kopā ar četriem metāla stūra leņķiem. Katrs stūra leņķa savienojums ar loksni nodrošināja stabilu platformas noturību.



62. att. Dēstu podiņu fotografēšanas stends ar regulējamu fotokameras augstumu

Platformas vidū tika izveidoti trīs caurumi: vidusdaļā atradās fotokameras lēca, kas novietota 90^{o} leņķī no plaknes ar skatu uz leju (uz augu lapām), tās diametrs 7.0 cm; blakus fotokameras lēcai atradās divi kabatas lukturi, to diametrs 2.5 cm un skats vērsts uz leju 90^{o} leņķī no plaknes. Apgaismojumam izmantoja divus LED lukturus "Arcas 9LED" (9 LED spuldzes, gaismas plūsma 50 lm.).

Fotoattēlus ar augiem uzņēma siltumnīcā kontrolētos apstākļos. Fotoattēli ar augiem to attīstības laikā (AE 09 – 16) tika uzņemti no 10 cm un 30 cm attāluma (attālums no augsnes virskārtas līdz kameras lēcai). Fotoattēlus uzņēma ar "Canon PowerShot G16" fotoaparātu (fotoattēlu izmēri 4000*3000 pikseļi, faila tips JPEG).

Stumjamās fotografēšanas platformas. Agrihortā tika izgatavotas divas stumjamas platformas, lai uzņemtu fotogrāfijas uz lauka. Platforma sastāv no 4 riteņiem, kur divi fiksētie un divi pagriežamie 13" riteņi, ar maksimālo pieļaujamo slodzi 136 kg uz vienu riteni. Riteņi vienai platformai piemetināti pie trīsstūrveida metāla kronšteina, bet otrajai pieskrūvēti pie kronšteina ar M10 vītņstieni un uzgriežņiem. No metāla U-veida montāžas profiliem

2x30x30x30 mm tika izveidots platformas karkass. Montāžas profilu savienošanai tika izmantoti M10 vītņstienis, paplāksnes un paškontrējošais uzgrieznis DIN 985.

63. att. Stumjamās fotografēšanas platformas karkass

Lai konstrukcija būtu stabilāka, vienai platformas versijai karkass nostiprināts ar 12 mm OSB plāksnēm. Lai vides apstākļi, piemēram, lietus neietekmētu platformas konstrukcijas un, lai tās ilgāk kalpotu, atrodoties apkārtējā vidē, platformas tika apšūtas ar difūzijas membrānu "DALTEX frameshield 100 plus". Otra platformas korpuss tika veidots no mitrumizturīgā 12 mm saplākšņa.

64. att. Stumjamā fotografēšanas platforma sagatavota darbam

Stumjamās fotografēšanas platforma fotoaparāta augstums ir regulējamas gan uz augšu, gan uz leju. Arī riteņu konstrukciju attālums savā starpā regulējams, padarot konstrukciju šaurāku vai platāku. Katrai zemnieku saimniecībai attālums starp riteņiem un fotografēšanas augstums tika pielāgots individuāli, jo vagu augstums un attālums starp kultūraugu rindām katrā saimniecībā bija atšķirīgs.

Saulainajā laikā, lai saule netraucētu kvalitatīvu attēlu uzņemšanu, papildus izveidoti regulējamie ēnotāji gan priekšā, gan sānos. Ēnotāji izgatavoti no elastīgu plastmasas cauruļu

(10 mm diametrā) karkasa, kurš pārklāts ar "DALTEX frameshield 100 plus" necaurspīdīgo materiālu.

Tā kā kultūraugu rindu novietojums atšķiras starp saimniecībām, platformās fotoaparātam ir paredzētas vairākas ievietošanas vietas un grīdā izgriezti atvērumi fotoaparāta objektīvam.

65. att. Fotoaparātu pozīcijas

Augu fotogrāfiju uzņemšanai tika izmantots fotoaparāts Sony Cyber-shot DSC-W800 ar 20.1 Mega pikseļa kameru 5x optisko palielinājumu. Lai nesabojātos un nesaskrāpētos fotoaparāts, ievietojot un veicot fotografēšanu, ievietošanas malas ir izgatavotas no ekstrudēta putupolistirola "Technoplex".

Pašgājēja fotografēšanas platforma. Platforma sastāv no metāla rāmja, akumulatoru un vadības nodalījuma, un četriem elektropiedziņas riteņiem. Pašgājējplatforma izgatavota LLU Tehniskajā fakultātē pirms projekta uzsākšanas un projekta gaitā pielāgota attēlu uzņemšanai.

66. att. Pašgājēja fotografēšanas platforma aprīkota ar kamerām un saules aizsegiem

Platforma tika aprīkota ar divām Intel RealSense fotokamerām, viena priekšā, ar skatu vagas virzienā, otra platformai pa visu, ar skatu uz augiem no augšas. Platformai iebūvēti vairāki gaismas avoti. Divi lukturi priekšā izgaismo braukšanas virzienu, bet divi LED prožektori vērsti uz augiem, lai fotografēšanas laikā kultūraugi un nezāles būtu pietiekami un vienmērīgi apgaismoti. Lai samazinātu saules gaismas ietekmi uz fotografējamo laukumu, no melna plastikāta izgatavots gaismu aizturošas sienas. Platformai tālāk tika uzstādīts attēlu iegūšanas aprīkojuma nodalījums, kurā izvietots dators, monitors, akumulatori un strāvas pārveidotājs.

67. att. Platformai uzstādīts attēlu iegūšanas aprīkojuma nodalījums

Projekta ietvaros pašgājēja fotografēšanas platforma papildus tika aprīkota ar saules fotovoltisko paneli virs attēlu iegūšanas aprīkojuma nodalījuma. Ar saules paneli saražotā enerģija, tika izmantota platformas akumulatoru lādēšanai.

68. att. Platforma tiek demonstrēta Lauksaimniecības zinātnisko iestāžu Direktoru Padomes skatē

Pēc vairākiem testiem tika nolemts papildināt saules aizsardzību, aprīkojot platformas sānus un priekšu ar saules sargiem no zaļa polikarbonāta plāksnēm. Saules sargiem priekšā un aizmugurē bija iespēja regulēt augstumu, tādā veidā pielāgojoties kultūrauga augstumam.

Fotografēšana ar statīvu. Dēstu kastēs audzēto augu fotoattēlu uzņemšanai tika izmantoti divi fotoaparāti: 1) “Canon EOS 800D” digitālais fotoaparāts (fotoattēlu izmēri 6000*4000 pikseļi, faila tips JPEG); 2) “Canon PowerShot G16” (fotoattēlu izmēri 1200*1200 pikseļi, faila tips JPEG). Fotoattēli tika uzņemti kontrolētos apstākļos ar telpas mākslīgo apgaismojumu un trīspunktu atbalsta fotostatīvu (Manfrotto). Uz trīspunktu atbalsta sistēmas fotoaparāts tika nostiprināts tā, lai lēca atrastos pretskatā pret augu lapām - lēcas skats tika vērsts no augšpuses uz leju. Tika iestatīts 30 cm attālums no fotoaparāta lēcas līdz dēstu kastēs esošās augsnes virskārtas.

69. att. Fotoaparāts ar statīvu dēstu kastu fotografēšanai

Fotoattēli ar augiem tika uzņemti vienreiz dienā no augu attīstības etapa (AE) – 09 (dīgsta parādīšanās no augsnes, dīgļlapas redzamas virs augsnes virskārtas) līdz AE – 16 (sešas īstās lapas izveidojušās).[5] Lai uzņemtu fotoattēlus ar augiem sānskatā, dēstu kaste tika savērsta (45^{o} leņķī no plaknes) no tās sākotnējā stāvokļa. Attēli tika uzņemti tā, lai attēlā ir redzams auga lapas virsmas laukums un forma.

2.3. Fotoattēlu uzņemšana lauka apstākļos

Fotoattēlu iegūšana lauka apstākļos notika sadarbība ar trīs projektā iesaistītajām saimniecībām:

1) Rūjienas novada, Jeru pagasta SIA "Lejasvagaļu dārzs", kur tika fotografēti cukīni un ķirbji;
2) Krimuldas novada, Krimuldas pagasta J. Lipska saimniecība "Absolūts Ēd", kur tika fotografēti redīsi un rutki;
3) Ķekavas novada Daugmales pagasta zemnieku saimniecība "Atvases", kur fotografēti burkāni un bietes.

Projekta norises laikā fotoattēlu uzņemšana norisinājās vairākkārt un dažādos augu augšanas attīstības etapos (sākot no dīgļlapu atvēršanās pilnībā virs augsnes virskārtas (AE – 10) līdz brīdim, kad izveidojušās sešas īstās lapas (AE – 16). Augi tika fotografēti pirms un pēc augsnes rindstarpu apstrādes (ravēšana, irdināšana), kā arī lietus un diennakts tumšajā laikā.

Stumjamā fotografēšanas platforma. Augu fotoattēlu uzņemšanai tika izmantots fotoaparāts Sony Cyber-shot DSC-W800 un Intel RealSense kameru. Stumjot platformu uz priekšu pa vagu ar augiem, ik pēc metra tika veikta manuāla fotografēšanas uzņemšanas pogas nospiešana. Attēli uzņemti dažādos rakursos, mainot fotoaparāta ievietošanas vietu. Tika

5 http://noverojumi.vaad.gov.lv/kulturaugu-fenologija/darzeni - atsauce uz augu attīstības etapiem

uzņemtas bildes un videoieraksti. Foto attēli uzglabājas fotoaparāta SD kartē un vēlāk tika pārkopēti uz servera tālākai foto apstrādei.

Atkarībā no saules atrašanās vietas fotografēšanas laikā, pirms fotografēšanas tika noregulēti saules sargi priekšā un sānos.

70. att. Stumjamā fotografēšanas platforma pie lauka ar nolaistiem saules aizsargiem

Pašgājēja fotografēšanas platforma. Platforma līdz laukam un pa kultūrauga rindu tika vadīta ar distances vadības pulti. Pirms kustības uzsākšanas pa lauku, tika ieslēgts vadības dators un aktivizēta automātiska augu vai vagu fotografēšanas programma. Virzot platformu pa vagu uz priekšu un atpakaļ, Intel RealSense fotokameras fiksēja augus no augšās uz leju vai skatu vagas virzienā. Ar automātisko režīmu datorprogramma spēj fotografēt 60 attēli/minūtē, ar iespēju iestatīt vairāk vai mazāk attēlus sekundē.

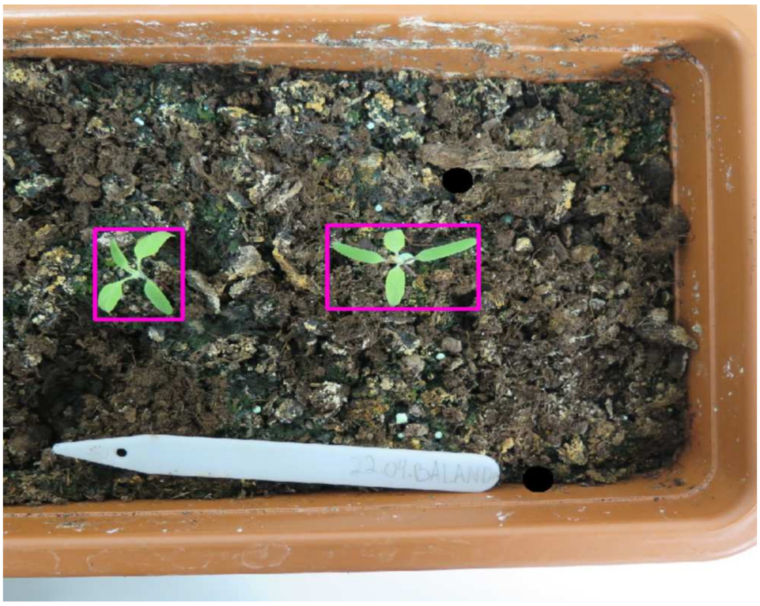
71. att. Pašgājēja fotografēšanas platforma darbībā uz mitras augsnes

Pašgājēja platforma testēta gan saulainā, gan lietainā laikā. Lietainajā laikā, kad zeme ir mitra, platforma braucot pa lauku, tērē vairāk enerģijas, jo robota masa ir ~150 kg un riteņi izslīd. Braucot pa slapju augsni, tas grimst zemē un nepieciešama lielāka jauda, lai izbrauktu visu maršrutu, līdz ar to akumulatori izlādējās ātrāk nekā sausā, saulainā laikā.

Platforma testēta arī nakts laikā. Darbību naktī nodrošina uzstādītie lukturi braukšanas virzienā un LED prožektori, kas izgaismo augus.

2.4. Fotoattēlu anotēšana

Fotoattēlu anotēšanai uz “Windows10 OS” tika izveidota speciāla programma, izmantojot python un cv2, xml.etree.ElementTree bibliotēkas. Lai izmantotu anotēšanas programmu augu atpazīšanai, katram kultūraugu un nezāļu sugai tika izveidotas dokumentu mapes “images” un “annotations”. Dokumentu mapē “images” ievietoja atlasītus fotoattēlus, kuros augu un/vai nezāļu attēli atbilda nepieciešamajai kvalitātei. Dokumentu mapē “annotations saglabājās katra attēla augu anotāciju klase un rāmīša koordinātas .xml failā. Lai anotētajos fotoattēlos augu suga un auga koordinātas tiktu savstarpēji sasaistītas, fotoattēlu faila nosaukumam jāsakrīt ar anotāciju faila nosaukumu.



72. att. Ekrānttēls no augu anotēšanas programmas

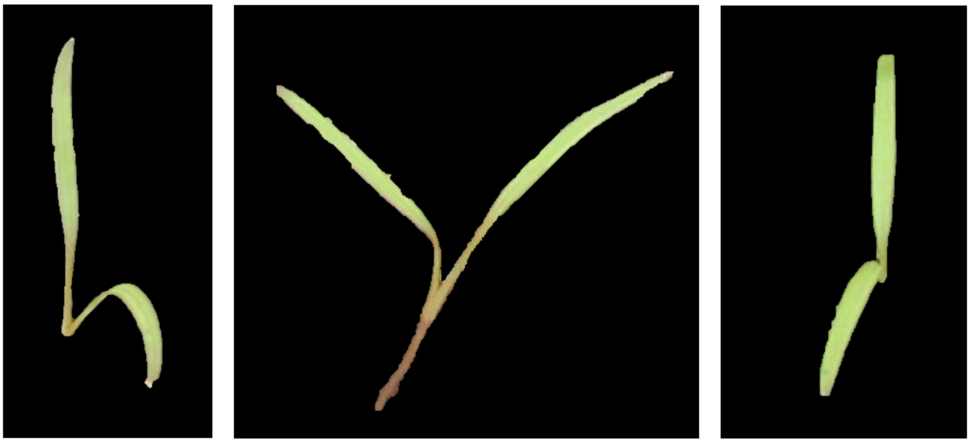
Anotēšanai izvēlējās tādu augu fotoattēlus, kuros labi saskatāmi augi. Anotētājs katrā attēlā apvilka taisnstūrveida anotēšanas rāmīti ap katru redzamo augu, no saraksta izvēloties atbilstošo auga sugu. Anotēja tos augus, kuru lapas savstarpēji būtiski nepārklājās ar citu augu lapām. Gadījumos, kad fotoattēlos redzamie augi un to lapas savstarpēji būtiski pārklājās, šos augus aizkrāsoja izmantojot lietojumprogrammatūru “Paint”.

Anotēšana tika veikta vairākos piegājienos, un sagatavotas vairākas datu kopas. Sagatavotās anotēto attēlu kopas tika nodotas atpazīšanas algoritmu apmācībai. Balstoties uz iegūto rezultātu, anotēšana tika turpināta iesāktajā veidā vai veiktas izmaiņas metodē. Piemēram, tika izmēģināts anotēt augus kas savstarpēji pārklājas ar vienu anotēšanas rāmīti. Iegūtie atpazīšanas rezultāti bija sliktāki, nekā anotējot katru augu atsevišķi, līdz ar to turpmāk tika anotēts katrs augs atsevišķi.

Vagu attēlu anotēšanai tika izveidota speciāla programma, kurā ar vektora palīdzību tika norādīts vēlamais kustības virziens.

73. att. Ekrānattēls no vagu marķēšanas programmas ar vēlamo robota kustības vektoru

Lai palielinātu kvalitatīvu augu attēlu daudzumu, viena no metodēm ir sintētisko attēlu veidošana. Tam nepieciešams no attēliem precīzi izgriezt augu zaļās daļas (angliski: *crop*) un tad šos izgrieztos augus ievietot attēlā ar augsnes fonu. Izgrieztos augus iespējams pagriezt dažādos leņķos un veidot to spoguļattēlus, tādejādi būtiski palielinot datu kopā ietilpstošo attēlu skaitu. Lai veiktu augu zaļās daļas izgriešanu, tika izmantota attēlu apstrādes programma "Paint 3D". Projekta ietvaros šī metode tika izmēģināta, bet, tā kā augu izgriešana ir ļoti laikietilpīgs process, tika nolemts šo virzienu tālāk neattīstīt.



74. att. No fotoattēliem izgriezti burkāna dīgstu attēli

3. Nezāļu atpazīšana un to atrašanās pozīciju noteikšana

Lai nodrošinātu robota darbību reālā laikā, kā viens no nozīmīgākajiem RVS centrāliem blokiem ir robota augu detektēšanas sistēma. Tās izveides un darbības procesa shēma sastāv no šādiem galvenajiem secīgiem posmiem: augu attēlu iegūšana, attēlu priekšapstrāde un marķēšana, dziļā neironu tīkla apmācīšana. Zemāk dots katra posma īss raksturojums projekta ietvaros.

Attēlu ieguvei sākotnējai apmācības kopai tika izmantotas Intel RealSense D435, Canon EOS 800D, Canon PowerShot G16 un Sony W800 digitālās RGB kameras. Ar kamerām Intel RealSense D435 un Sony W800 tika iegūti augu attēli lauku apstākļos, bet ar Canon EOS 800D un Canon PowerShot G16 kontrolētos apstākļos. Lauku apstākļos attēli tika iegūti Ķekavas, Rūjienas un Krimuldas novados, bet kontrolētos apstākļos Jelgavā. Iegūto attēlu izšķirtspējas bija atšķirīgas kā 720x1280, 1000x750, 640x480, 640x360 u.c. Jāpiezīmē, ka attēlu punktu izšķirtspēja pirms attēlu apmācības dziļā neironu tīkla ieejā tika pārrēķināta.

Attēlu marķēšanai tika pielietos “objektu izgriezuma princips”. Augu marķēšana datu kopas izveidei tika veikta manuāli, izmantojot *python* un cv2, xml.etree.ElementTree bibliotēkas. Projekta ietvaros tika sagatavotas vairākas attēlu kopas. Kā viena no attēlu kopām tika izveidota datu kopa, sastāvoša no 1118 marķētiem attēliem, kuros tika klasificēti seši kultūraugi un astoņas nezāļu sugas, kopumā tikai iegūtas 7853 anotācijas, kas apkopota projekta SCOPUS publikācijā[6]. Tāpat augu detektora izveidei tika lietota projektā izveidotā atvertā datu kopa[7].

3.1. Algoritmi augu atpazīšanai

Lai robota datorredze atpazītu nezāles no kultūraugiem, tas ir jāapmāca. Augu atpazīšanai attēlos apmācībai tika izmantota vienas pakāpes pielāgots konvolūcijas dziļo neironu tīkls (CNN) YOLOv2 un YOLOv4[8]. Izmaiņas arhitektūrā tika veiktas, palielinot tā ieejas slāņu skaitu un pielāgojot atbilstošu atpazinēja izeju nepieciešamajām detektēšanas klasēm. Turklāt augu atpazīšanas sistēma konfigurēta tādā veidā, lai apstrādātu attēlus ar 1216x1216 punktu izšķirtspēju. Lai gūtu priekšstatu attiecībā uz izvēlēto pielāgoto konvolūcijas neironu tīkla “dziļumu”, vērtīgi atzīmēt, ka tas sastāv no 21 konvolutīvā slāņa.

Kā citus pamata apmācības raksturlielumus jāmin, - tīkla apmācības ātrums 0,0001, *batch* 8. Apmācībai tika izmantoti 90%, bet validācijai 10% no datu kopas attēliem. Objektu atpazīšana attēlos veikta ar *Darkflow* izstrādes ietvaru[9] un pamatā ir lietota programmēšanas valoda *python*. Apmācība veikta uz EDI rīcībā esošā HPC (*High Performance Computer*) servera, kas nodrošina nepieciešamo grafisko veiktspēju, lai apmācītu neironu tīklus.

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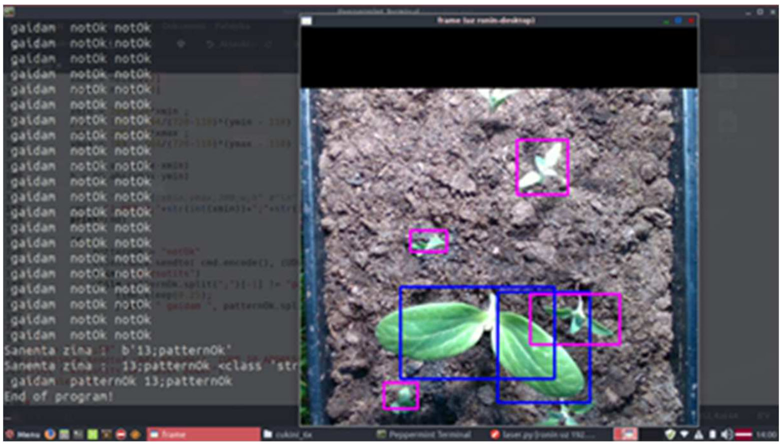
[6] Sudars, K., Jasko, J., Namatevs I., Ozola L., Badaukis, N. (2020). Dataset of annotated food crops and weed images for robotic computer vision control, Data in Brief, 31. doi:10.1016/j.dib.2020.105833
[7] https://makonis.edi.lv/s/kiwBSk78C8iY94W
[8] https://pjreddie.com/darknet/yolo/
[9] https://github.com/thtrieu/darkflow

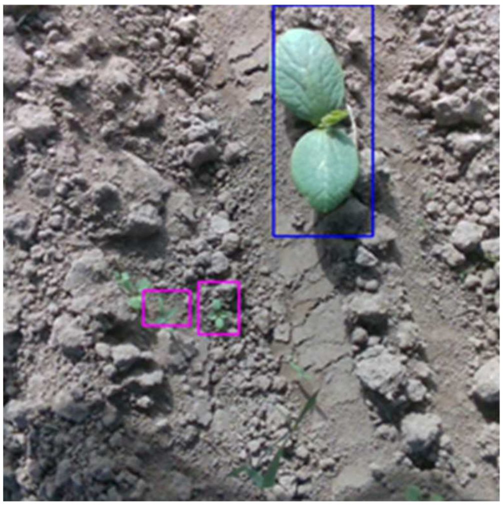
Augu atpazīšanas sistēma attēlos

Projekta gaitā tika izstrādātas sešas augu atpazinēju versijas, veicot apmācību uz dažādām projektā izveidotām augu datu apmācības kopām, ko noteica, definējot dažādas augu detektēšanas klases (75.attēls).



75. att. Nezāļu un kultūraugu detektēšana.

Kā 75. attēlā redzams augu detektora programmas izsaukšanas darbības interfeiss sastāv no augu attēla un papildus informācijas programmatūras konsoles, kurā tiek sniegta informācija par koda izpildes un nezāļu ierobežošanas gaitu. Zemāk 76. attēlā dots augu detektora attēlos piemērs.

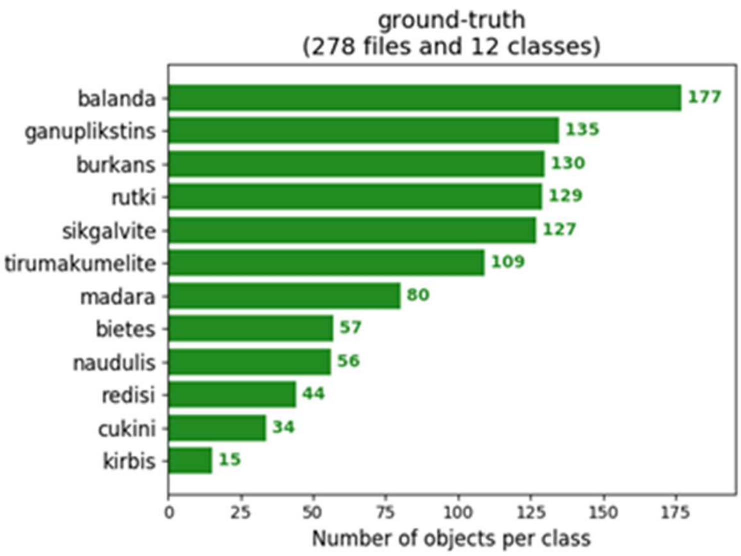


76. attēls. Augu detektēšana.

Iespējams redzēt, ka tiek izgriezti, ierāmēti un atšķirti atpazītie kultūraugu un nezāles.

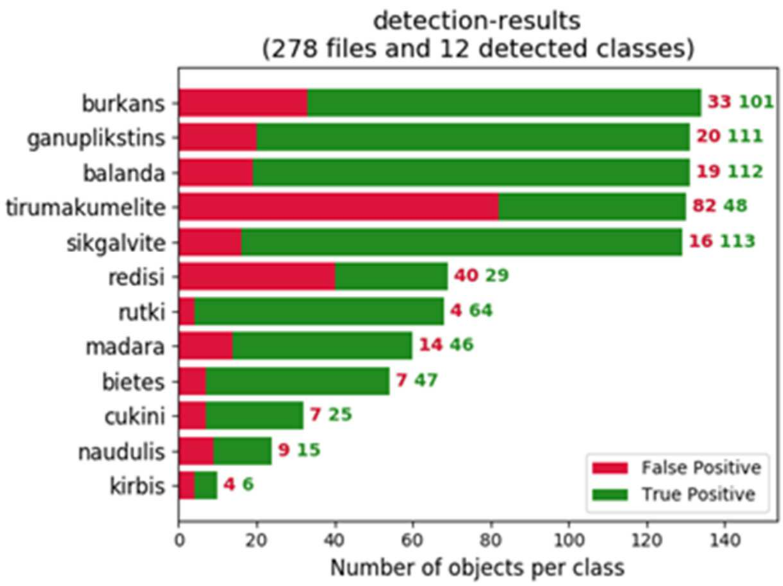
Augu atpazīšanas sistēmas detektēšanas rezultāti

Augu atpazīšanas sistēmas detektēšanas rezultātu apkopojuma absolūtajās frekvencēs slokšņu diagrammā uz vienas no testa datu kopas (*n* testa datu kopa) skat. 77. attēlā.



77. att. Detektēšanas atpazinēja augu sadalījuma pa klasēm, n testa kopa

Zemāk 78. attēlā diagrammā parādīta apmācībā izmantotās datu kopas sadalījums pa klasēm un objekta detektēšanas precizitāte, fiksējot veiksmīgi atpazīto un kļūdaini atpazīto objektu skaitu.



78. att. Detektēšanas atpazinēja augu sadalījuma pa klasēm un klašu detektēšanas precizitāte, n testa kopa

Šādi objektu atpazīšanas rezultāti sasniegti tikai ar pēdējām atpazinēja versijām. Tas izskaidrojams, ka bija nepieciešams laiks, lai izveidotu pienācīgu dziļā neironu tīklu datu apmācības kopu. Kā arī, lai pieskaņotu atbilstošu konvolūciju neironu tīkla atpazinēja arhitektūru un hiperparametrus. Jaunākā augu atpazinēja versija ir pieejama uz Elektronikas un datorzinātņu institūta servera[10].

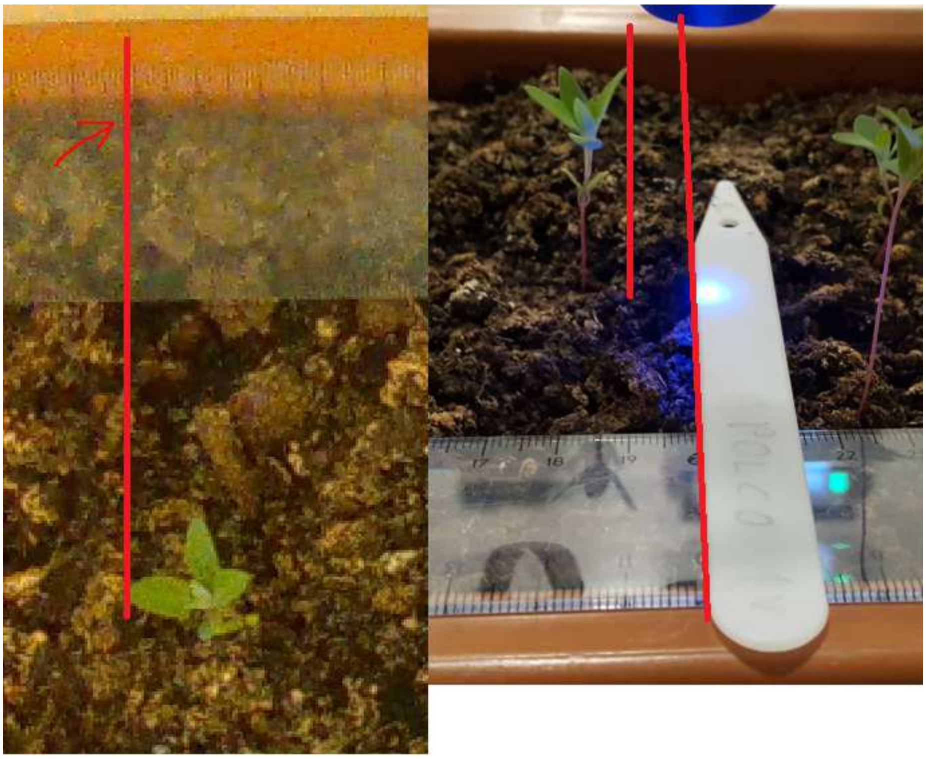
[10] http://git.edi.lv/kaspars.sudars/ronin_weed_detector

Lai augu atpazīšanas sistēma nevainojami darbotos ir jāņem vērā visi faktori, apstākļi un nosacījumi, kas nosaka un sastāda augu apmācības datu kopu. Kā piemēri jāmin, augu attīstības stadija, attēlu ieguves parametri u.tml. Tie savukārt ir cēloņi, kas definē, kādas attēlu marķēšanas vadlīnijas izvēlēties un izveidot prasībām atbilstošas kvalitātes objektu atpazinējus attēlos.

No augu atpazinēja iegūtās nezāļu koordinātas tiek pārrēķinātas no pikseļiem uz cm dabā un uz šīm koordinātām tiek virzīts vai nu lāzers, vai mehāniskās ierobežošanas rīks.

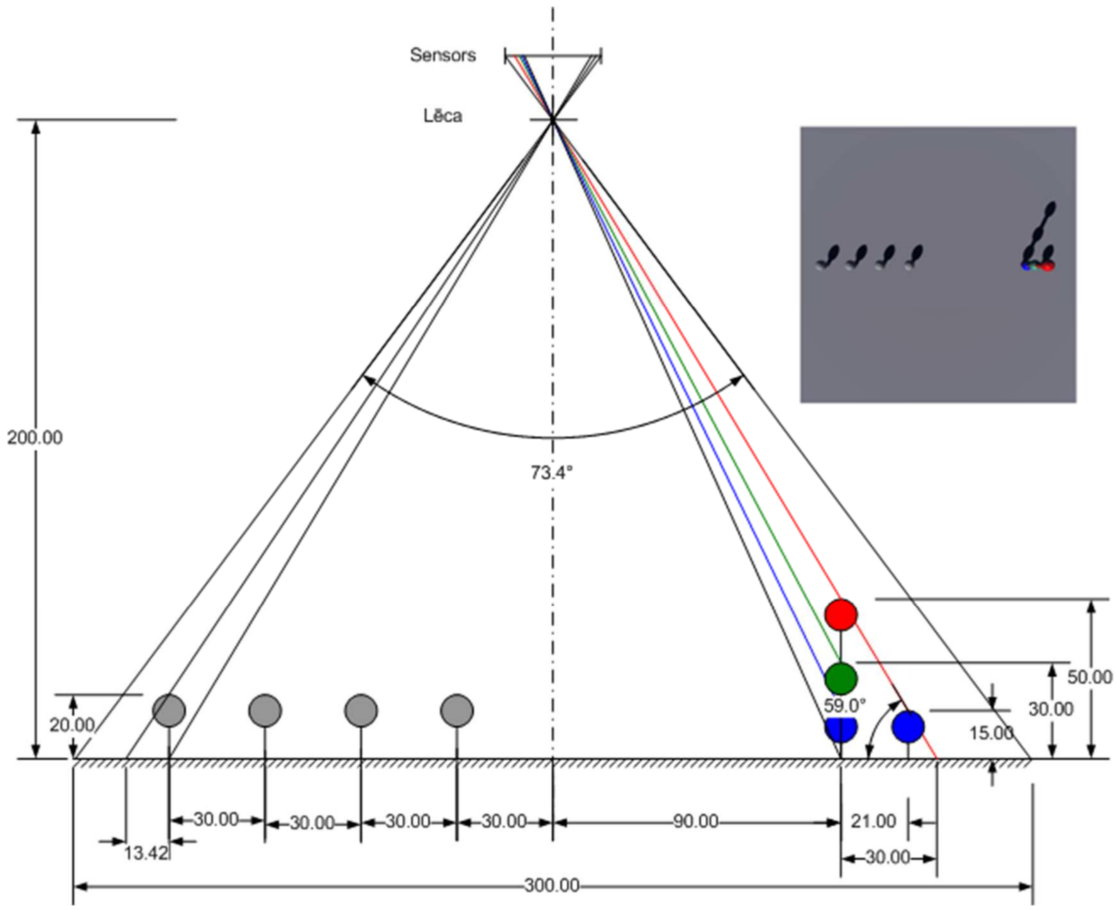
3.2. Nezāles atrašanās koordināšu 3D telpā noteikšana

Lāzera manipulators attiecībā pret nezālēm tika vērsts vertikāli, imitējot scenāriju ar mobilās robota platformas lāzera stara kustības virzienu. Arī fotoattēlu uzņemšana notiek virsskatā attiecībā pret augiem. Šādā konfigurācijā jārisina optiskās perspektīvas parādība, kad augs atkarībā no atrašanās vietas attiecībā pret kameru dažādi izskatās uzņemtajā fotoattēlā. Jo augstāks augs, un jo tālāk augs atrodas uz sāniem no kameras optiskā centra, jo lielāks perspektīvas efekts, kas programmātiski jākompensē, lai precīzi trāpītu ar lāzeri uz auga virsmas. Perspektīvas efektu var redzēt 79. attēlā. Faktiskā atšķirība uz lineāla sastāda aptuveni 1 cm, kā rezultātā nekompensējot šo starpību lāzers trāpītu garām.



79. attēls. **Perspektīvas efekts.** Pa kreisi attēls skatā no augšas, kur sarkanā līnija norāda uz auga robežu. Pa labi attēls skatā no sāniem, kur labā sarkanā līnija sakrīt ar kreisā attēla sarkano līniju, savukārt kreisā sarkanā līnija parāda faktisko auga robežu.

Perspektīvas efekts rada situāciju, kad augsta objekta punkti sakrīt ar punktiem attēlā, kuri ir nobīdīti no kameras centra. Shematiski tas ir parādīts 80. att. Objekts ar sarkano riņķi galā kameras skatā (pelēkais kvadrāts) pilnībā pārklāj 15 mm augsto objektu ar zilo riņķi, kurš atrodas pa labi no tā.

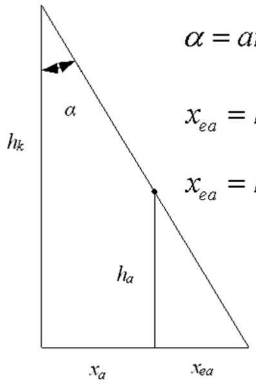


80. att. Objektu pārklāšanās dēļ perspektīvas kameras skatā, visi izmēri milimetros, atbilstoši projektā plānotai robota konfigurācijai

Pārklāšanās efektu ir iespējams aprēķināt ar trigonometrijas palīdzību pēc algoritma, kas dota 81. att. Blakus grafikā redzamas aprēķinātās nobīdes x_{ea} atkarībā no attāluma līdz kameras optiskajam centram. Piemēram, augiem ar 30 mm augstumu šī nobīde sastāda aptuveni 20 mm, ja tie atrodas 150 mm attālumā no centra (pie 300x300 mm apstrādes laukuma).

Perspektīves radītā problēma ir risināma divos veidos.

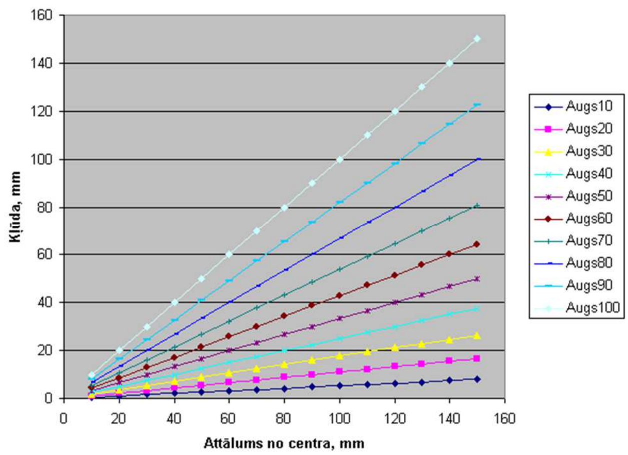
- veikt augu augstuma mērījumus, piemēram, ar dziļuma kameru vai ar divām kamerām (stereo redze);
- pieņemt vidējo augu augstumu ar kuru tiks strādāts un rēķināties ar nobīdes kļūdu.



$$\alpha = arctg\left(\frac{x_a}{h_k - h_a}\right)$$

$$x_{ea} = h_a \cdot tg(\alpha)$$

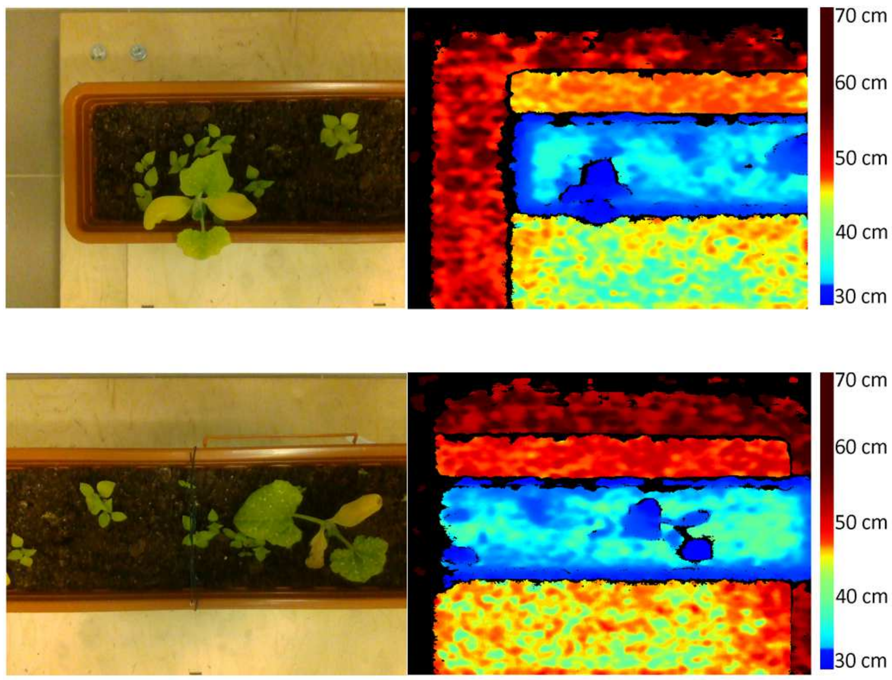
$$x_{ea} = h_a \cdot \frac{x_a}{h_k - h_a}$$



81. att. Perspektīves nobīdes aprēķini dažāda augstuma augiem: x_a - auga attālums no centra; h_k - kameras augstums (200 mm); a - auga galotnes redzamais leņķis; h_a - auga augstums; x_{ea} - kamerā redzamā nobīde

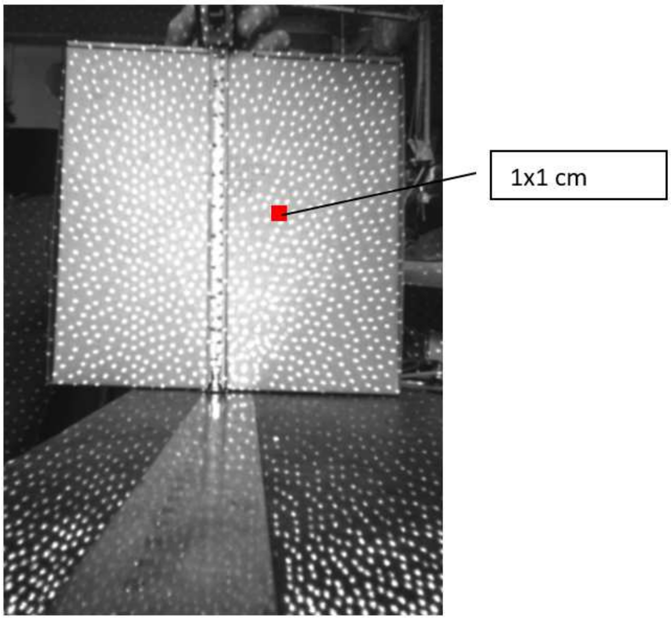
Dziļuma kameras izmantošana

Augu 3D formas un pozīcijas telpā noteikšanas funkcionalitāte tika realizēta, izmantojot Intel RealSense D435 dziļuma kameru. Informācija par augu 3D formu un pozīciju telpā nepieciešama, lai varētu kompensēt ierobežojošo iekārtu pozicionēšanas nobīdi, kura rodas dēļ perspektīvas efekta 2D attēlā augiem virs zemes plaknes. Uzņemto attēlu paraugi RGB un dziļuma diapazonā doti 82. att.



82. att. RGB attēls un dziļuma attēls ar attālumiem līdz kamerai

Izmantotās dziļuma kameras darbības pamatā ir aktīvā infrasarkanā stereo dziļuma mērīšana, kura izmanto lāzera emiteru, lai projicētu punktu režģi, pēc kura deformācijām nosaka katra attēla punkta attālumu no kameras. Režģa izmantošana uzlabo lielu objektu attāluma noteikšanas precizitāti. Tomēr ne visi augi var tikt detektēti ar šādas pieejas palīdzību, jo režģa solis robotam paredzētajā darba attālumā (40 cm) pārsniedz 1 cm, kas definē minimālo detektējamo objektu izmēru (skat. 83. att.).



83. att. RealSense D435 projecētais dziļuma noteikšanas režģis 40 cm attālumā

Ņemot to vērā, šādas dziļuma kameras izmantošana ir lietderīga augiem, kuri ir vismaz 4x4 cm un lielāki.

3.3. Attēlu apstrāde, lai pārbaudītu nezāles iznīcināšanu

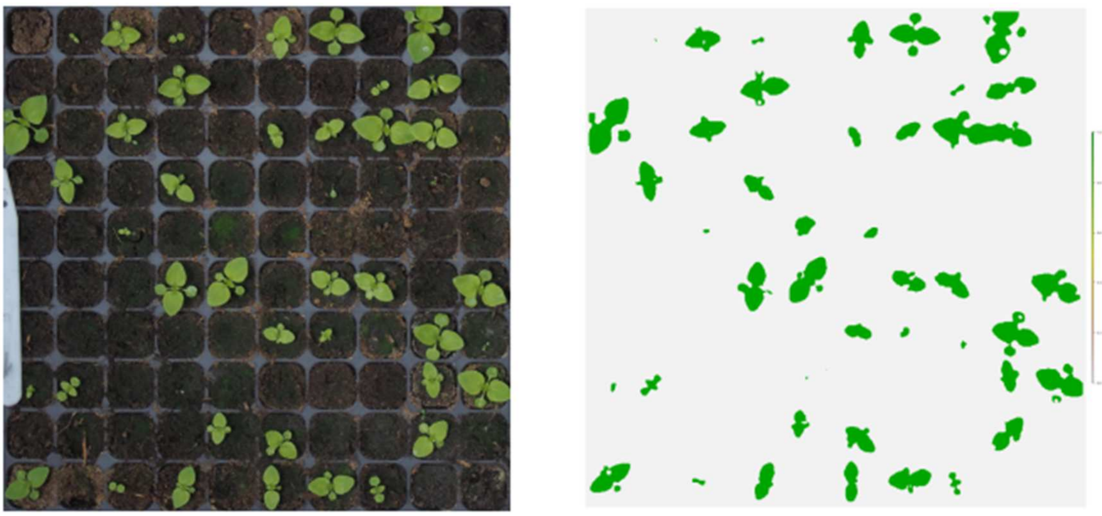
Lai novērtētu to vai nezāļu ierobežošanas agregāts ir apstrādājis nezāli, tika izveidots algoritms, kas fotogrāfijās pirms un pēc auga apstrādes un ļauj novērtēt kopējo augu zaļo daļu laukumu. Šim nolūkam tika izveidots skripts “R statistics” vidē. Par pamatu tika ņemts augu zaļās krāsas indekss[11]. Zaļā augu masa tika identificēta pēc sekojošas formulas:

$$I = \frac{2G - R - B}{2G + R + B},$$

kur I – zaļās masas indekss

R, G, B – krāsu komponentes sarkans, zaļš zils.

84. att. dots piemērs ar zaļā laukuma identificēšanas skripta rezultātu. Lai panāktu attēlu savstarpēju salīdzināmību, visi eksperimentālie augi tika fotografēti stingri no viena augstuma, nemainīgā apgaismojumā, precīzu augu kastes novietošanas pozīciju pret fotoaparātu un nemainīgiem fotoaparāta iestatījumiem (palielinājums, atvērums, ekspozīcijas laiks un ISO jutība).



84. att. Krāsu fotogrāfija (pa kreisi) un augu zaļā laukuma noteikšana (pa labi)

No attēla izgūtie zaļie pikseļi tiek izteikti skaitliskā vērtībā - indeksā un ir iespējams aprēķināt augu zaļā laukuma indeksa izmaiņas pirms un pēc apstrādes.

[11] A database for remote sensing indices. [tiešsaiste][26.01.2021] Pieejams: https://www.indexdatabase.de/db/i-single.php?id=35

4. Nezāļu ierobežošanas iekārtas pozicionēšanas un orientēšanas moduļu izstrāde

Lai nodrošinātu robota autonomu darbību, iekārtai nepieciešams orientēties apkārtējā vidē un spēt virzīties pa zemnieka uzdotu maršrutu. Līdzīgi kā citiem autonomiem transportlīdzekļiem robota pozicionēšanai pamatā tiek lietota satelītnavigācijas sistēma, kas papildināta ar kultūrauga vagas (rindas) atpazīšanas algoritmu. Atšķirībā no viedtālruņos lietotās satelītnavigācijas sistēmas, kuras precizitāte aptuveni 2-4m, GNSS-RTK moduļi atkarībā no apkārtējās vides, spēj darboties ar precizitāti līdz pat 3 cm. Tas nodrošina, ka robots virzīsies pa definēto maršrutu ar augstu precizitātes pakāpi.

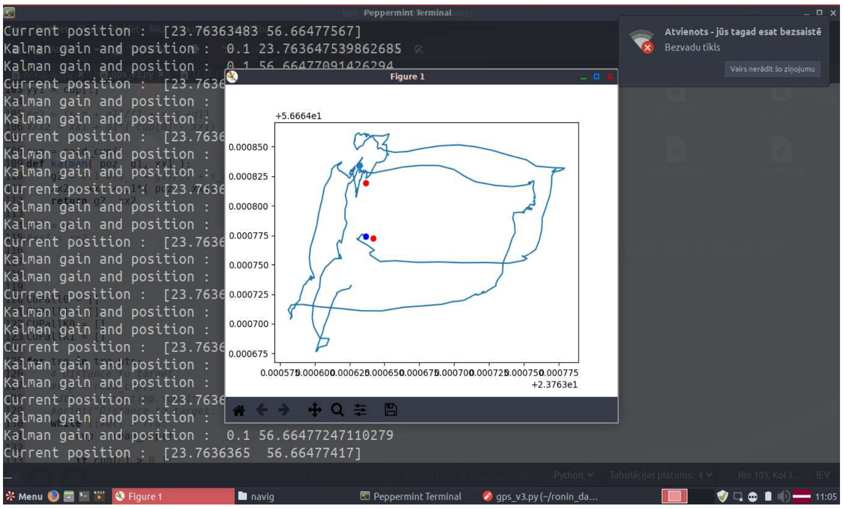
4.1. GNNS RTK robota vadīšanas moduļa un algoritmu izstrāde

Lai nodrošinātu robota autonomu pārvietošanos no bāzes vietas līdz lauka sākumpunktam, kā arī veiktu kustību pa vagām, robots izmanto satelītnavigāciju. Plašāk zināmā no globālās navigācijas satelītu sistēmāmām (GNSS) ir Amerikas Savienoto Valstu uzturētā Globālās pozicionēšanas sistēma (GPS), bet papildus tai darbojas arī Galileo (Eiropa), GLONASS (Krievija) un BeiDou (Ķīna) sistēmas, kuru satelītu signālus arī ir iespējams izmantot. Satelītnavigāciju papildinot ar reālā laika kinemātikas (RTK) funkciju, ir iespējams noteikt robota atrašanās vietu ar <10 cm precizitāti un atbilstoši koriģēt robota kustības gaitu. Lai izveidotu maršrutu robotam, nepieciešama GNSS punktu koordinātu ierakstīšana robota atmiņā. Kad robota navigācijas sistēma pārslēgusies precīzajā režīmā, robots spēj pārvietoties pa definēto maršrutu ar augstu precizitātes pakāpi. Lai nodrošinātu robota darbības precizitāti, t.i., lai GNSS RTK sistēma spētu darboties augstās precizitātes režīmā, ir nepieciešama GNSS RTK bāzes stacija. Tās uzdevums ir sūtīt robotam tā atrašanās vietas pozīciju korekcijas.

GNNS RTK moduļu izvēle un precizitātes novērtējums.

Projekta ietvaros tika izvērtēti dažādi tirgū pieejamie GPS RTK risinājumi, kuri gan precizitātes, gan cenu līmeņa ziņā būtu piemēroti uzstādīšanai uz robota. Kā atbilstošs tika izvēlēts u-blox ražotāja C94-M8P modulis[12], kas atbalsta bāzes stacijas un mobilās platformas konfigurācijas iespēju. Iekārtas testi parādīja, ka iekārta ir precīza, un spēj nostabilizēties augstas precizitātes režīmā, vienlaikus ir ar salīdzinoši zemu stabilitāti. Iekārta pārsvarā atradās zemāka līmeņa precizitātes režīmā, un ļoti reti spēja nostabilizēties vajadzīgajā precizitātes režīmā. Stabilitātes uzlabošanai tika veikti testi ar Kalmana filtra pielietošanu (skat. 85. att.).

[12] https://www.u-blox.com/en/product/c94-m8p



85. att. GPS RTK mērījumi un stabilitātes uzlabošana ar Kalmana filtru

Projekta gaitā GPS RTK iekārtu tirgū kļuva pieejams nākamās paaudzes u-blox modulis C099-F9P[13]. Balstoties uz produkta tehniskajiem aprakstiem, tika secināts, ka tam vajadzētu būt stabilākam par savu priekšgājēju. Divi C099-F9P moduļi tika sakonfigurēti bāzes un mobilās platformas režīmā, un tika veikti analoģiski signāla un precizitātes režīma stabilitātes testi. Tika secināts, moduļi tiešām darbojas stabili, un saglabāja augsto precizitātes režīmu, tiklīdz tas tika sasniegts.

C099-F9P modulis tika izvēlēts turpmākiem eksperimentiem, kā piemērotāka iekārta precizitātes un veiktspējas dēļ. Vispirms tika veikts koordinātu noteikšanas tests statiskā režīmā. Šim nolūkam tika uzņemti četri punkti dabā ar C099-F9P iekārtu un pārbaudīti pret iepriekš uzmērītām punktu koordinātām. Vispirms QGIS rīkā[14] tika atzīmēti punkti (skatīt 86. att.)

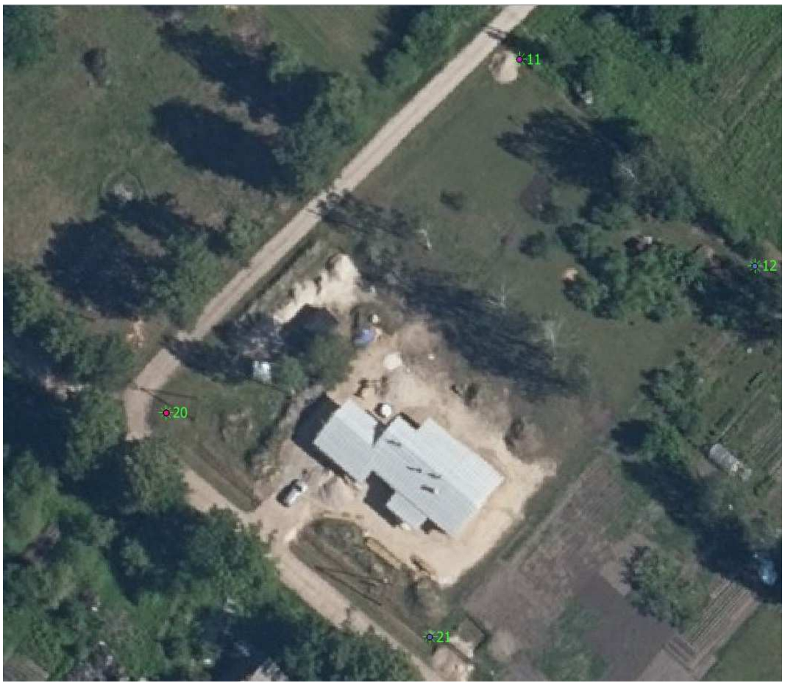
86. att. GNSS RTK precizitātes tests ar uzmērīto punktu koordinātām

[13] https://www.u-blox.com/en/product/c099-f9p-application-board
[14] https://qgis.org/en/site/

Viens no C099-F9P moduļiem, kas bija nokonfigurēts kā references bāzes stacija tika novietots uz paaugstinājuma, lai nodrošinātu moduļu savstarpējo kumunikāciju, bet ar otru moduli, kas bija nokonfigurēts mobilās platformas režīmā, tika secīgi pārvietots pa izvēlētajiem punktiem. Katrā punktā tika ierakstīts nomērīto GPS koordinātu žurnālfails, tālākai apstrādei un datu attēlošanai QGIS rīkā. Tālāk tika veikts koordinātu noteikšanas tests dinamiskā režīmā, pārvietojot moduli un tādā veidā imitējot mobilās platformas kustību. Visu mērījumu žurnālfailu saturu var redzēt 10. pielikumā. Iegūtie dati tika papildus pievienoti QGIS rīkā jau atzīmētajiem punktiem kartē (skatīt 87. att.).

87. att. GNSS RTK precizitātes testi - novērojama konstanta koordinātu nobīde X un Y ass virzienā.

Eksperimentu rezultātos tika novērota konstanta koordinātu nobīde, kas skaidrojama ar to, ka uz testu brīdi modulim, kas bija nokonfigurēts kā references bāzes stacija, nebija iestatītas fiksētas antenas ģeogrāfiskās koordinātas. Šajā eksperimentā bāzes stacija pati noteica savu atrašanās vietu noteiktu laiku, līdz tika sasniegta minimālā iestatītā precizitāte. Kad minētie nosacījumi izpildījās, bāzes stacija pārgāja raidīšanas režīmā līdz ar to otra moduļa GNSS koordinātu absolūtā precizitāte ir tieši atkarīga no pirmā moduļa noteiktajām GNSS koordinātām kalibrēšanas režīmā. Pēc 10 dienām tika veikts atkārtots eksperiments statiskā režīma precizitātes novērtēšanai. Šajā reizē references bāzes stacijas koordinātas tika iestatītas statiskas, par pamatu ņemot uzmērītās koordinātas, tādējādi šim modulim vairs nebija jāveic paškalibrācija. Mērījumi līdzīgi kā pirmajā eksperimentā tika saglabāti žurnālfailos (skatīt 11. pielikumu) un dati tika pievienoti QGIS rīkā. Pateicoties fiksētām bāzes stacijas antenas koordinātām, otrā moduļa GNSS koordinātas ir daudz precīzākas un kļūda bija samazinājusies no aptuveni 2.5 m līdz 13 cm ņemot vērā mērījuma kļūdu un uzmērīto punktu precizitāti dabā (skatīt 88. att.).



88. att. GNSS RTK otrie precizitātes testi - koordinātas sakrīt 13 cm robežās.

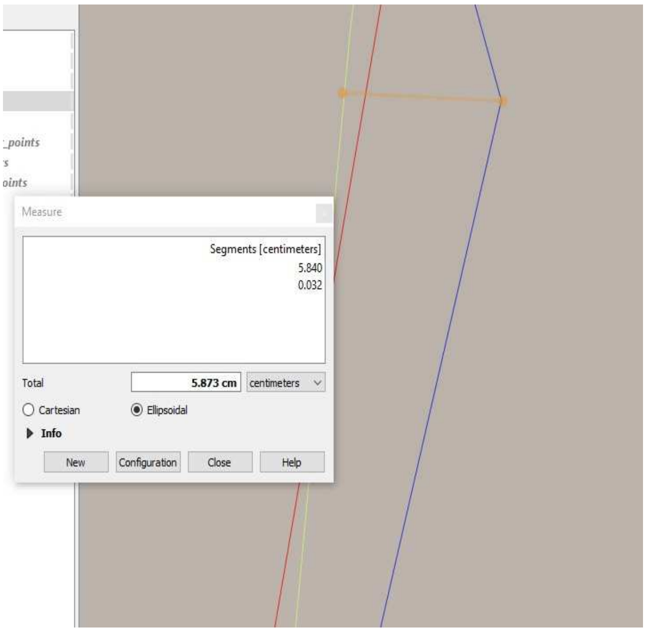
Starp precizitātes eksperimentiem notika dinamiskā režīma eksperiments Agrihorta teritorijā. Šajā eksperimentā tika novērtēta relatīvā moduļa precizitāte un atkārtojamība. Laukumā pie Agrihorta ēkas tika izveidota ģeometriska figūra - astoņstūris (skatīt 89. att.).

89. att. GNSS RTK relatīvās precizitātes testi Agrihorta teritorijā.

References bāzes stacijas modulis tika novietots brīvi izvēlētā vietā, savukārt mobilā robota pārvietošanās imitācijas moduļa antena tika piestiprināta koka vadīklai un vadīkla tika pārvietota pēc iespējas stabili un precīzi attiecībā pret izveidoto astoņstūri. Tika veikti trīs apļi un mērījumi saglabāti žurnālfailos (skatīt 12. pielikumu) vēlākai attēlošanai QGIS rīkā (skatīt 90. att.).

90. att. GNSS RTK relatīvās precizitātes testu 3 atkārtojumi

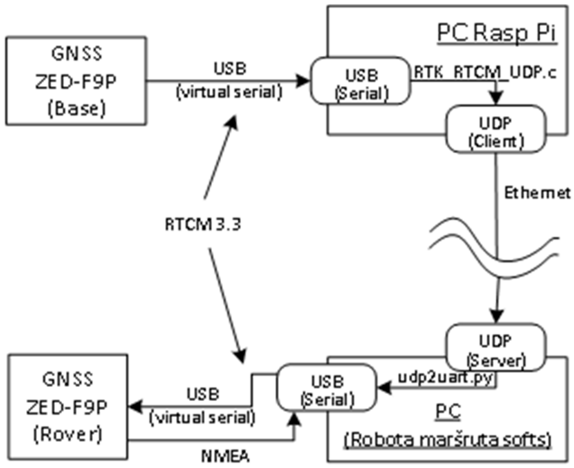
Atkārtojumi liecina par augstu precizitāti un mērījumu atkārtojamību. Ņemot vērā mērījuma kļūdu, antenas pārvietojuma kļūdu nobīde starp atkārtojumiem nepārsniedz 10 cm (skatīt 91. att.).



91. att. GNSS RTK relatīvās precizitātes testu trīs atkārtojumu trajektorija tuvplānā

GNSS RTK vadības shēma

Satelītnavigācijas sistēmas izmantošanai robotam tika izmantota 92. attēlā redzamā shēma. GNSS ZED-F9P moduļi ir pieslēgti pie datoriem *Raspberry Pi* (kontrolē bāzes staciju) un robota borta datoram Jetson. Savienojumu starp datoriem veido LAN tīkls, bet paši GNSS moduļi savienoti ar datoriem caur USB portiem.



92. att. Bāzes stacijas (attēlā Raspberry Pi) savienošanas shēma ar robota borta datoru (attēlā PC)

Lai nodrošinātu veiksmīgu robota sistēmas darbību un to, ka tā spēs sasniegt nepieciešamo precizitātes pakāpi statiskos apstākļos, navigācijas sistēma pirms uzstādīšanas uz robota platformas tika testēta EDI, skat 93. attēlā. Navigācijas programmatūras moduļi pēc tam tika testēti uz robota platformas jau pietuvinātā darbības vidē.

Visa programmatūra, kas izstrādāta robota vadīšanai caur GPS punktiem, ir uzstādīta uz robota Jetson borta datora un pieejama kopā ar robotizēto nezāļu ierobežošanas sistēmu. Vadības programmatūras kods ir pieejams uz EDI servera[15].

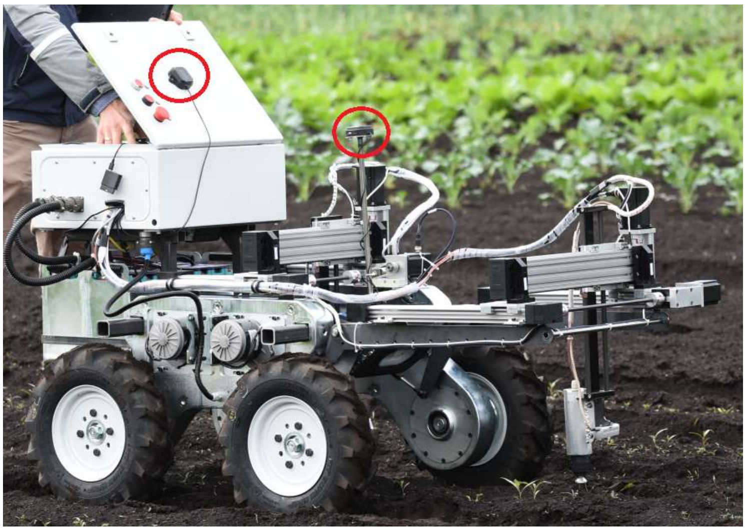
93. att. GNSS-RTK moduļu izmēģināšana uz EDI ēkas jumta pirms uzstādīšanas uz robota platformas

[15] https://makonis.edi.lv/s/gY8sT56nWpEa7GH

Robota satelīnavigācijas vadīšanas moduļa izstrāde sākumā tika veikta ar V1 platformu, testējot gan vienas, gan divu antenu izmantošanas iespējas.

94. att. Satelītnavigācijas algoritmu testi ar V1 platformu

Precīzas pozīcijas noteikšanai uz robota ir uzmontētas divas simetriski novietotas GNSS antenas. Tādā veidā pozīcija ar augstu precizitātes pakāpi tiek noteikta divos punktos. Šāds risinājums dod iespēju noteikt ne tikai robota atrašanās vietu, bet arī robota atrašanās virzienu (atšķirt robota priekšu no aizmugures). Tas ir būtiski, lai nodrošinātu to, ka robota platforma ir pagriezta ar pareizo pusi brukšanas virzienā.



95. att. Uz robota uzstādītas divas GNSS antenas (iezīmētas ar sarkaniem apļiem)

Izmantojot robota vadības planšeti, iespējams ierakstīt maršruta punktus, pa kuriem robotam jādodas no bāzes vietas līdz lauka sākumpunktam, kā arī vagu koordinātas. Izmantojot saglabātos koordinātu punktus, robots autonomi spēj pārvietoties pa vēlamo maršrutu. Vairāk par robota vadības saskarni lasāms 5. nodaļā.

4.2. Vagu virziena atpazīšanas algoritms

Lai veiktu robota autonomu vadīšanu pa vagu, konkrētos gadījumos papildus GNSS-RTK sistēmai pielieto vagu atpazinēja korekciju. Tā tiek rēķināta šādi, vispirms vagu atpazinējs ieejā saņem attēlu, kā ir parādīts 96. att. Tālāk tiek aprēķināts robota virziens no tā centra virzienā uz vagas centru, kā tas parādīts 97. att.

96. att. Vagu virziena atpazīšanas sistēmas ieejas attēla piemērs

Projekta laikā tika izskatītas vairākas pieejas, kā veidot vagas atpazīšanas sistēmu. Tika eksperimentētas un analizētas praktiskai pielietošanai šādas pieejas. Sistēmas izejas tika veidotas: 1) kā signāli, kas tieši vada robotu, 2) kā divas rekomendācijas robotam nākamajā solī pagriezties vienu vienību pa labi vai pa kreisi, 3) kā vektors, kas norāda virzienu uz tuvākās vagas centru. Eksperimentu laikā kā veiktspējīgākā izrādījās 3. pieeja, skat. 97. attēlu. Robota vadības programma no atpazinēja saņem korekcijas vektoru un to izmantot robota gaitas korekcijā, braucot cauri iepriekš definētiem augstas precizitātes GPS punktiem.

97. att. No robota kameras frontāli uzņemts lauka attēls, zaļā līnija, - robota kustības virziens, sarkanā līnija, - vagu atpazinēja ieteiktais robota griešanās virziens

Augstāk redzamajā attēlā parādīts vēlamais robota kustības virziens (zaļais vektors) un vagas virziena novērtējums no vagas atpazīšanas sistēmas (sarkanais vektors). Pēdējais iegūts no robota kameras, kas piemontēta frontāli un simetriski robota garenasij pie tā priekšpuses robota kustības virzienā, ja šo virzienu attiecina robota kustības plaknei. Vairāk rezultātu atrodams EDI serverī[16]. Izstrādātais programmatūras kods sistēmas darbībai ir instalēts un darbojas uz RONIN robotizētās platformas borta datora.

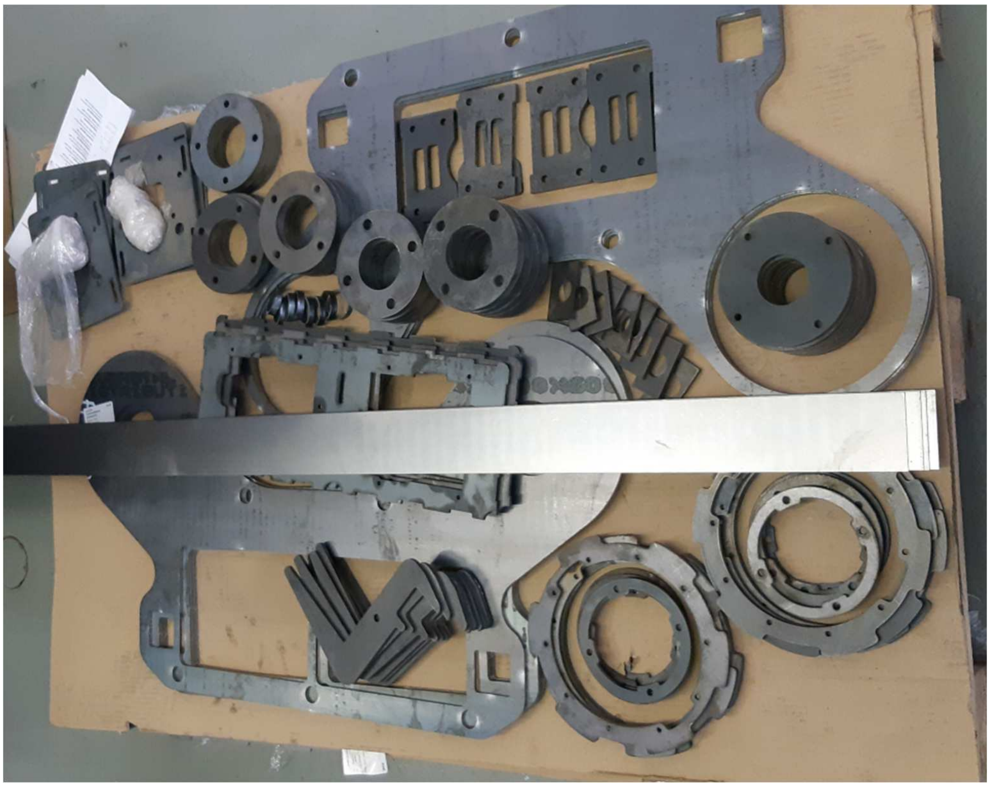
[16] https://makonis.edi.lv/s/gY8sT56nWpEa7GH

5. Izstrādāto moduļu integrēšana un iekārtas testēšana lauka apstākļos

Pēc veiksmīgas atsevišķo mehānisko mezglu un programmatūras pamatelementu izstrādes, tika veikta robota konstruēšana un savietošana vienotā iekārtā.

5.1. Atsevišķo mezglu savietošana vienotā iekārtā un sistēmu atkļūdošana.

Vienu daļu no detaļu rasējumiem nosūtīja uzņēmumam, kas nodarbojas ar metāla lāzergriešanu. Kad lāzergriešanas darbi veikti, gatavās (izgrieztās) metāla detaļas uz paletes atgādātas uz to turpmāko izgatavošanas un montāžas vietu, kas notika LLU Tehniskās fakultātes laboratorijas telpās.



98. att. Ar lāzergriešanas paņēmienu izgatavotās detaļas.

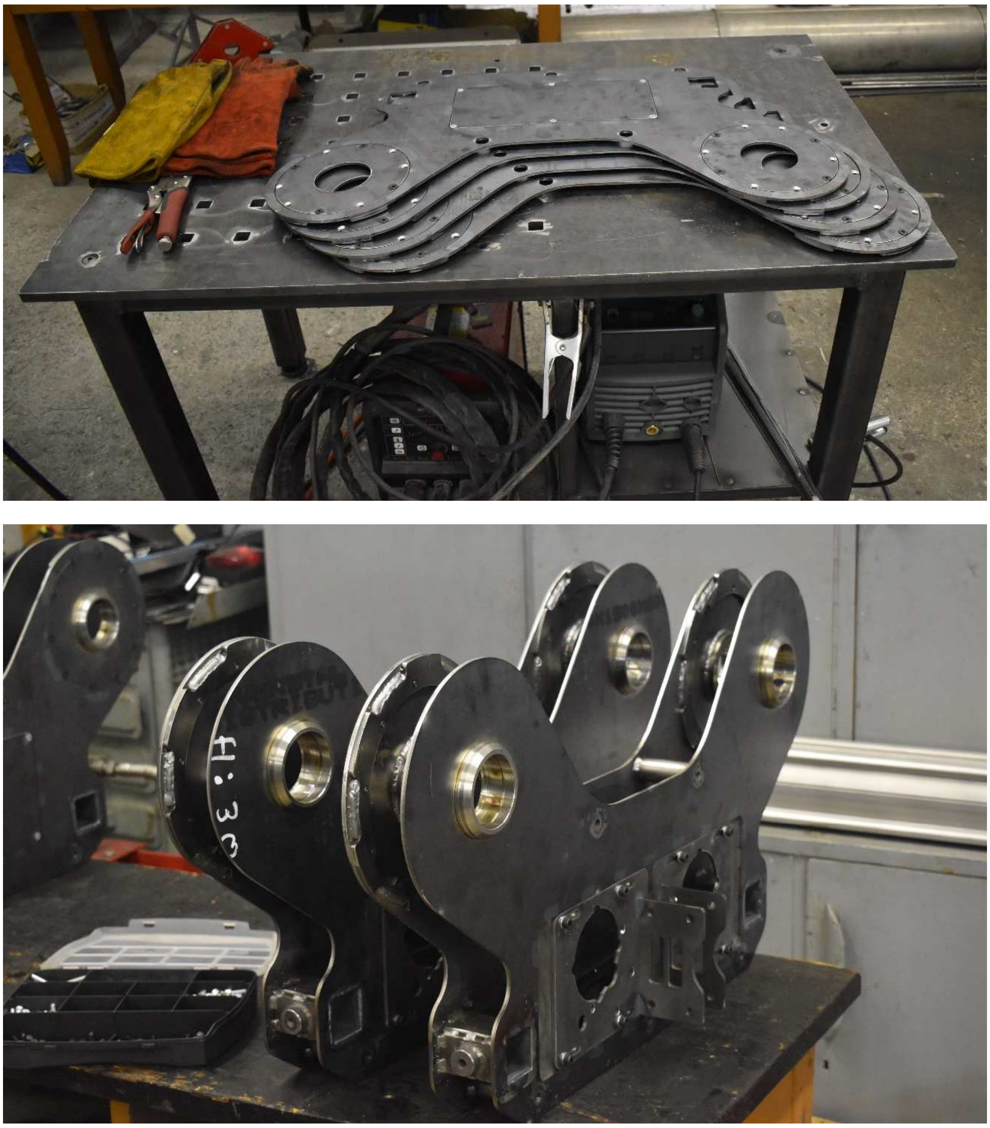
Tālāk visas metāla detaļas tika mehāniski apstrādātas, pieslīpētas griezuma vietas, veikti papildus urbumi un fāzējumi, iegrieztas vītnes utt. Vītņotie savienojumi tika izveidoti visos flančos, pie kuriem tiks pieskrūvēti vāki un citi elementi.

Paralēli mehāniskajiem sagatavošanas darbiem daļa no uzrasētajiem elementiem tika izgatavoti ar virpošanas vai frēzēšanas paņēmienu. Tika izvirpotas riteņu asis, riteņu rumbas, gultņu sēžu vietas, ķēžratu atloki un daudz un dažādas citas detaļas, kas nepieciešamas platformas izstrādei.

99. att. Detaļu mehāniska sagatavošana.

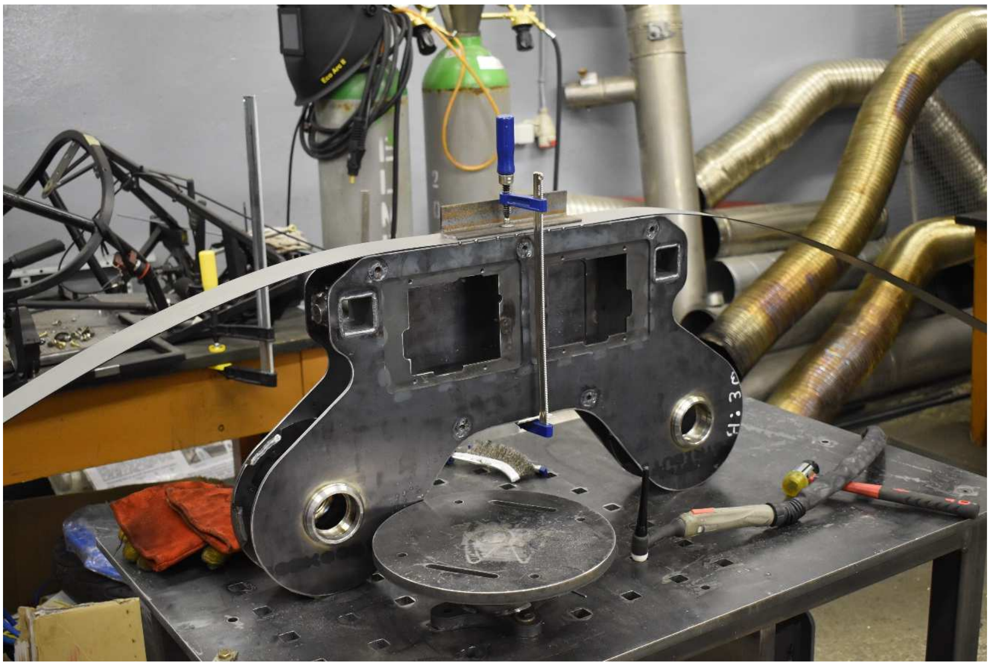
100. att. Daļa no izvirpotajām detaļām.

Tad, kad detaļas mehāniski sagatavotas, sākās detaļu metināšanas un montāžas process. Metināšanas veikta gan ar MIG/MAG paņēmienu, gan arī TIG paņēmienu. Sākotnēji sametināti atsevišķie elementi, kuru piekļuve nav iespējama pēc platformas sametināšanas, tad sāktas likt kopā platformas sānu bloku malas un tās sametinātas pie speciāli izvirpotiem distanceriem.

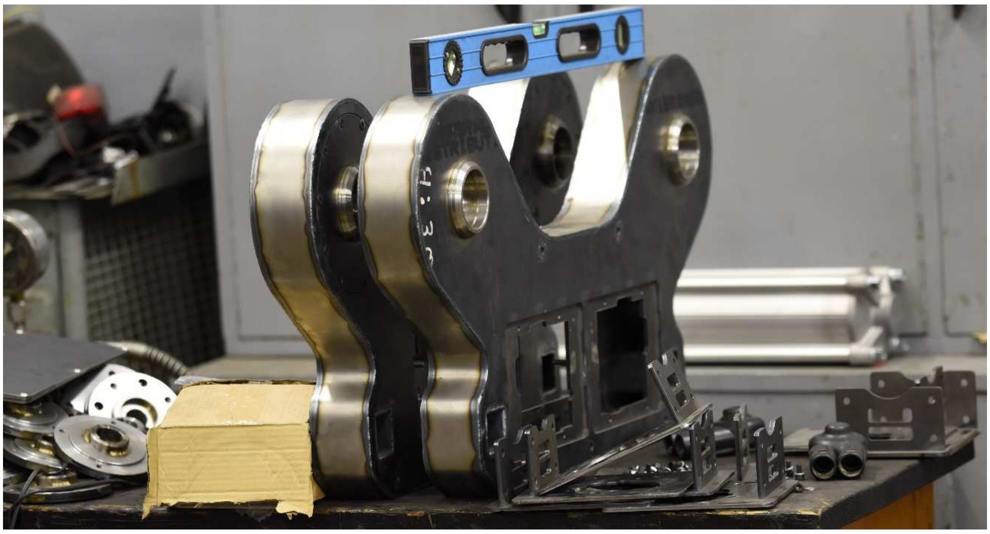


101. att. Sānu bloku izgatavošanas process – metināšanas darbi

Kā viena no noslēdzošām sānu bloku izgatavošanas sastāvdaļām ir aptverošās loksnes izlocīšana un piemetināšana pie sānu bloku malām. Ar šo darbību tiek noslēgti sānu bloka metināšanas darbi un šis bloks veidojas kā viena neizjaucama sastāvdaļa, pie kuras turpmākajā procesā tiks pieskrūvēti dažādi elementi un iemontēti piedziņas elementi.



102. att. Sānu bloku aptverošās loksnes izlocīšana un metināšana.

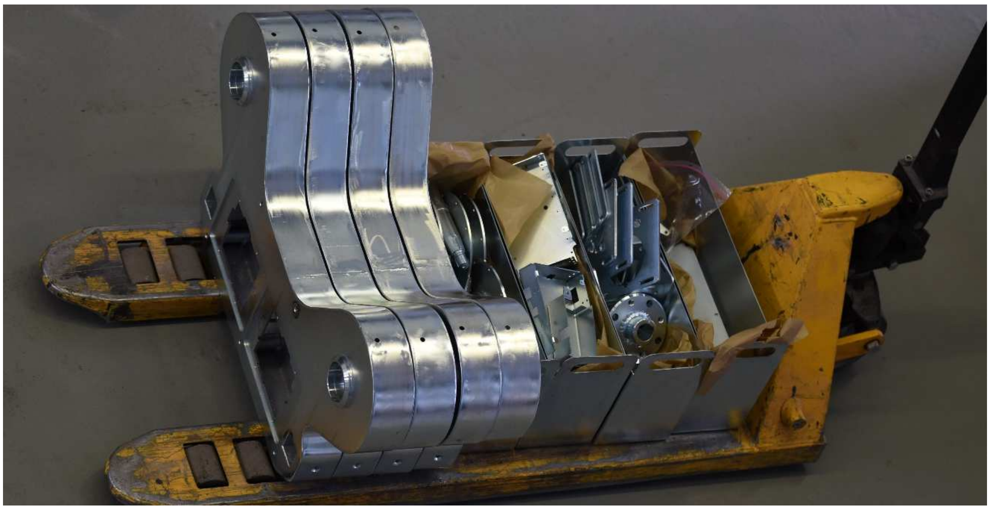


103. att. Atsevišķo elementu izskats pēc to metināšanas darbiem.

Tad, kad visas detaļas izgatavotas, tās tiek pieslīpētas, lai nebūtu nekādu nelīdzenumu vai metināšanas šļakatu. Tālāk visas platformas daļas tiek nogādātas uz uzņēmumu, kas veic detaļu cinkošanu.

104. att. Detaļas sagatavotas cinkošanai.

Šajā gadījumā izmantots aukstās cinkošanas paņēmiens, kas rada vizuāli pievilcīgāku metāla pārklājumu un nerada detaļas deformācijas cinkošanas laikā, kā tas var gadīties ar karstās cinkošanas paņēmienu.



105. att. Detaļas pēc cinkošanas.

Pēc cinkošanas visas detaļas atgādātas uz to turpmāko montāžas un komplektēšanas vietu.

Sekojošajā attēlā parādītas tikai vienā sānu blokā izmantotās detaļas un elementi. Papildus izlāzerētajām un izvirpotajām detaļām nepieciešami arī standartizētie elementi, t.i. elektromotori, piedziņas ķēžrati, ķēdes, gultņi, blīvslēgi, sprostgredzeni, skrūves, paplāksnes un uzgriežņi.

106. att. Sānu piedziņas bloka detaļas pirms to montāžas.

Tālāk notiek detaļu montāžas process, kad tiek sakomplektētas visas mehāniskās daļas.

107. att. Samontēts sānu piedziņas bloks.

Analoģiski pirmā sānu bloka izveidei tiek izgatavoti arī pārējie.

108. Att. Nezāļu iznīcināšanas robota braucamā daļa bez elektronikas

Pēc braucamās daļas izgatavošanas seko CNC mehānismu montāža. Arī paši CNC mehānismi no piegādātāja tika piegādāti izjauktā veidā, līdz ar to bija nepieciešamība tos samontēt. CNC mehānismu stiprināšanai izveidots atsevišķs rāmis, kurš vienkārši ir uzmontējams vai demontējams no braucamās platformas.

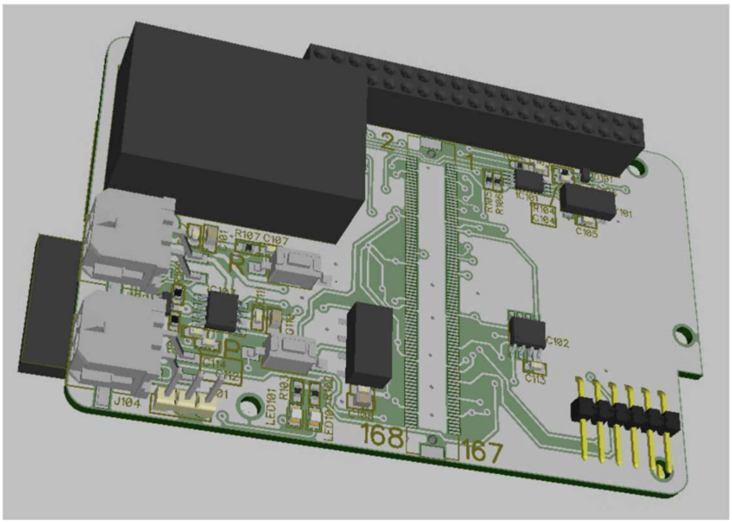
109. Att. CNC mehānismu montāžas procesā

Pēc nezāļu ierobežošanas platformas mehānisko komponenšu izgatavošanas un montāžas, seko visu vadības elementu uzstādīšana un elektrotehniskie darbi, jeb elektroinstalāciju montāža.

110. att. Robota vadības elementu integrēšana un elektroinstalācijas darbi

5.2. Robota centrālā vadība

Lai vadītu robota atsevišķos mezglus un koordinētu to darbības, projekta ietvaros tika izstrādāta vadības mikroshēma - robota centrālais vadības bloks. Robota centrālais vadības bloks nodrošina izpildmehānismu, robota riteņu un citu izpildelementu saskaņotu darbību ar borta datoru un GNSS-RTK sistēmu.

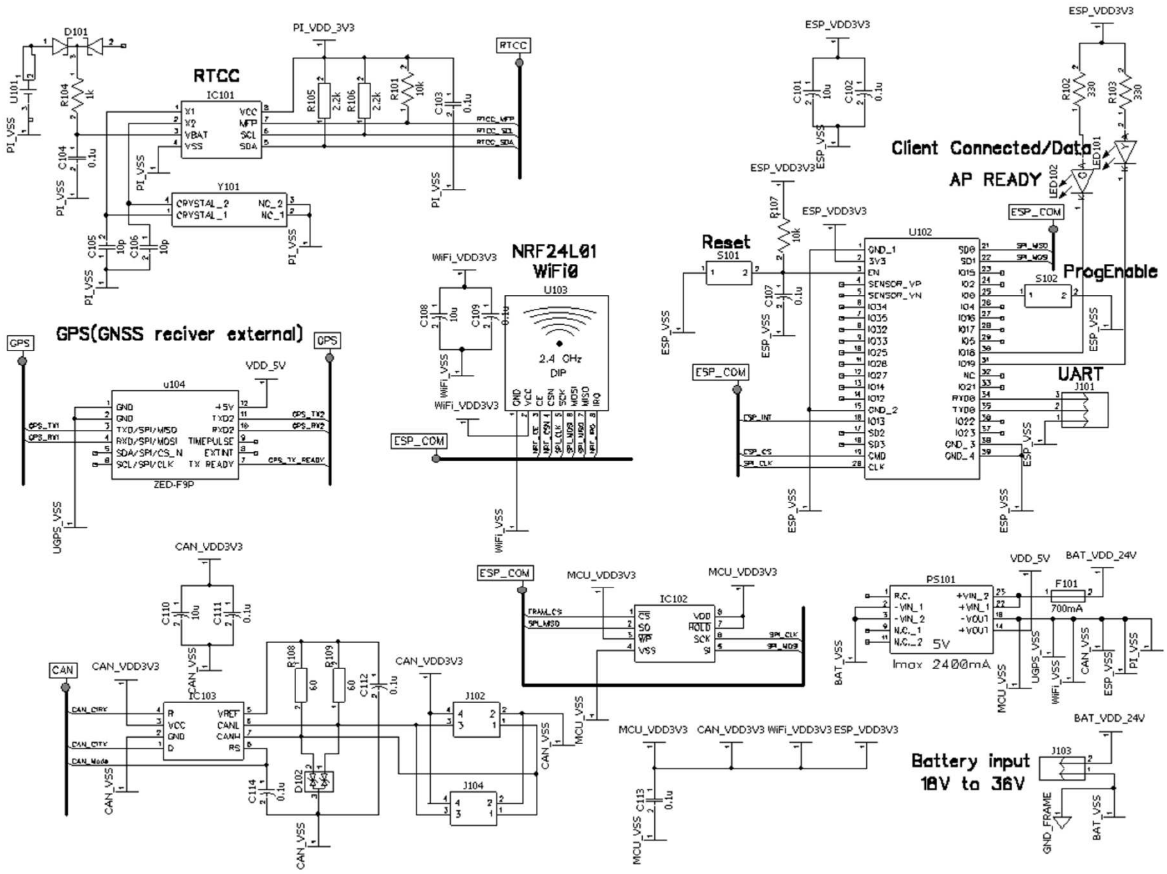


111. att. Robota centrālais vadības bloks

Par pamatu robota centrālajam vadības blokam izmantota Microchip izstrādes plate. Šai izstrādes platei pievienoti klāt dažādi papildus moduļi, lai robots pilnvērtīgi veiktu plānotās funkcijas. Shēma sastāv no vairākiem funkcionāliem papildus blokiem (skat. attēlā 111.b.):

- Kā viens no blokiem ir RTC (nodrošina reāllaika pulksteni), un šo funkciju pilda mikroshēma MCP79410 (shēmā apzīmēta ar IC101)
- Komunikāciju ar motora draiveriem un CNC nodrošina SN65HVD230D mikroshēma, (shēmā IC103).
- Robota telemetrijas datu saglabāšanai tiek izmantota mikroshēma IC102.

- Paredzētas papildus bezvadu komunikācijas 2.4 Ghz frekvencē NRF24L01 (U103) un ESP (U102).
- Paredzētas pieslēgvietas GPS moduļiem caur pieslēguma konektoru U104.



111.b. att. Vadības bloka shēmas

Centrālā vadības bloka programmatūra tika izstrādāta Microchip MPLABX vidē, izmantojot XC32 C valodas kompilatora brīvi pieejamo versiju un Microchip Harmony 2.0 satvaru.

Pielikumā doti galvenie funkcionālie un konfigurēšanas koda faili, ieskaitot automātiski ģenerētos CANOpen vārdnīcas failus komunikācijai ar piedziņas un CNC motoru kontrolleriem, kā arī modificētus galvenes failus atvērtā koda bibliotēkas CANOpenNode (https://github.com/CANopenNode/CANopenNode) izmantošanai.

6. tabulā dots projekta vajadzībām izstrādātā un automātiski ģenerētā koda failu kopsavilkums. Pilns MPLABX projekts pieejams 20. Pielikumā.

6. tabula.

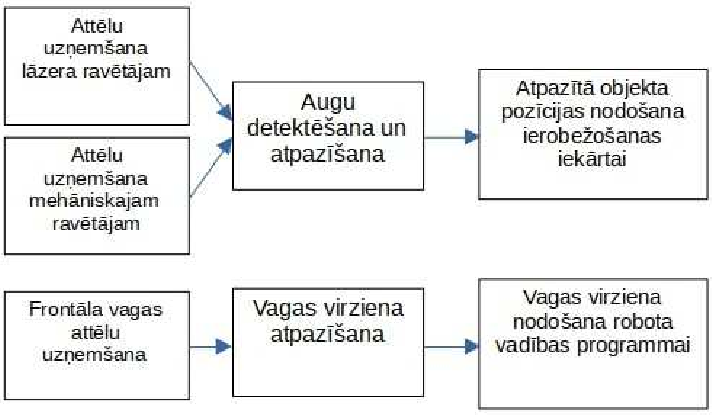
Centrālā vadības bloka koda failu kopsavilkums

app.c	Galvenais aplikācijas kods – apvieno stāvokļu mašīnā visu pārējo moduļu kodu
app.h	
CANopenApp.c	Aplikācija darbam ar CANOpenNode funkcionalitāti
CANopenApp.h	
CO_config.h	CANOpen konfiguācija
CO_driver_custom.h	
CO_driver_target.h	
CO_OD.c	CANOpen iekārtas vārdnīca (automātiski ģenerēts kods, izmantojot https://github.com/robincornelius/libedssharp)
CO_OD.h	
communicatorApp.c	Aplikācija komunikācijas organizēšanai ar vadības datoru
communicatorApp.h	
igusD1.c	IGUS D1 soļu motoru kontrolleru interfeisa aplikācija
igusD1.h	
main.c	Ieeja programmā
Ronin_CNC.c	CNC iekārtas vadība ar IGUS D1 soļu motoru kontrolleru palīdzību
Ronin_CNC.h	
Ronin_command_proc.c	No vadības datora saņemto komandu procesors
RoninCommandProc.h	
Ronin_laser.c	Lāzera vadības kods
Ronin_laser.h	
Ronin_mill.c	Zemes frēzes vadības kods
Ronin_mill.h	
Ronin_motor.c	Piedziņas motoru kontrolleru vadības kods
Ronin_motor.h	
simple_queue_config.h	Konfigurācijas kods queue datu struktūras izmantošanai

Robota kameru darbība, attēlu atpazīšana un satelītnavigācija tiek vadīta ar borta datoru. Tas saņem signālus no sistēmas atpazinējiem, GNNS antenām un rokas vadības planšetes. Lai veiktu augu atpazīšanu un detektēšanu attēlos, kā robota borta dators tika izvēlēta Nvidia Jetson AGX Xavier skaitļošanas platforma. Apsvērumi, kas noteica šādu izvēli, bija divi. Pirmkārt, zems enerģijas patēriņš, lai nodrošinātu robota ilgdarbīgu. Otrkārt, skaitļošanas jauda, kas būtu ekvivalenta personālā datora grafiskā procesora kartei (GPU).

112. att. Robota borta dators Nvidia Jetson AGX Xavier
(foto: developer.nvidia.com/embedded/jetson-agx-xavier-developer-kit)

Robota atpazinēju vadības sistēma spēj precīzi orientēties laukā, atšķirt nezāles no kultūraugiem un nosūtīt komandas, lai tās ierobežotu (113. att.).

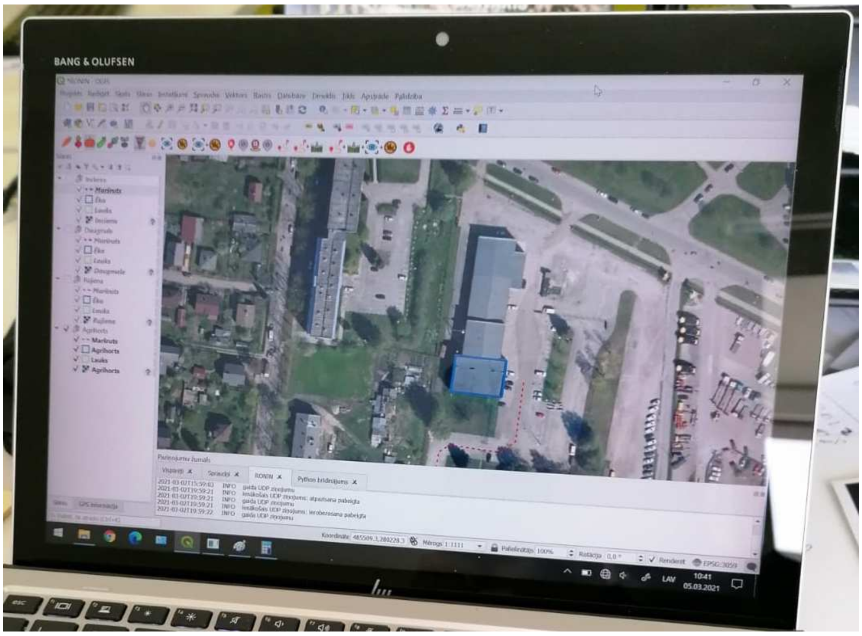


113. att. Atpazīšanas rezultātu adresācija atpazinēju vadības sistēmai, blokshēma

Lai nezāļu ierobežošanas agregāti tiktu pozicionēti uz nepieciešamajās vietām, tika veikta iegūto attēlu pikseļu un atrašanās vietas dabā savstarpējā salāgošana – izpildmehānismu kalibrēšana.

114. att. Nezāļu ierobežošanas agregātu kalibrēšana

Lai nodrošinātu lietotājam ērtu robota vadību, kā arī vizualizētu atgriezenisko saiti ar robota borta datoru, robotam pieslēgta vadības planšete. Vadības planšetē uzstādītā grafiskā saskarne aprakstīta 5.2. nodaļā.



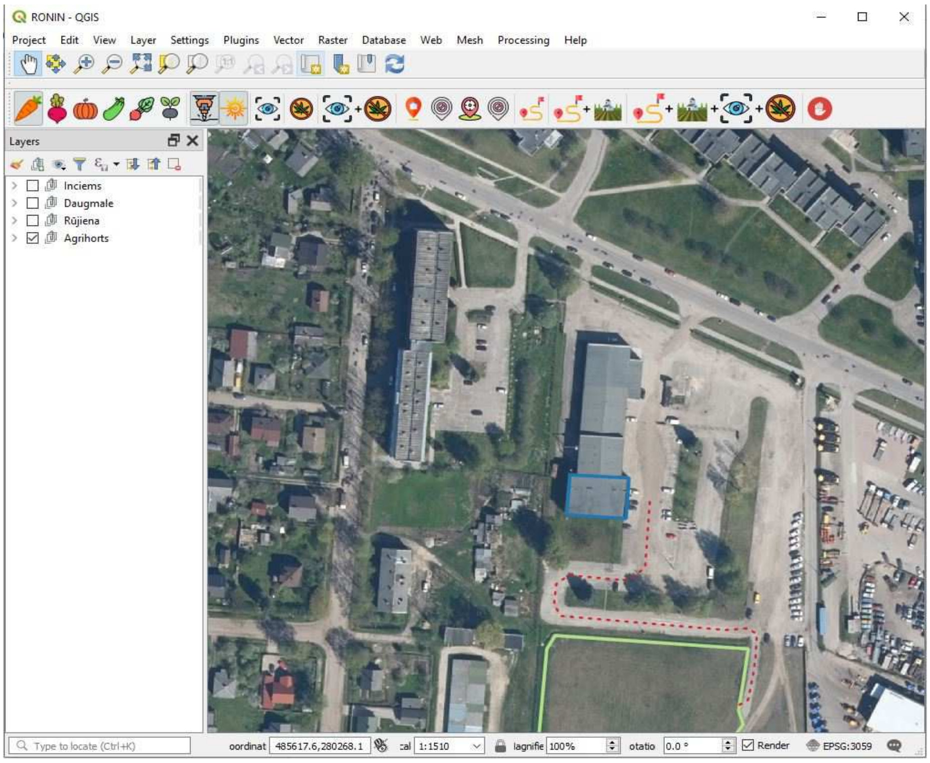
115. att. Robota vadības planšete

5.3. Robota vadības grafiskā saskarne

Robota vadības grafiskajai saskarnei jānodrošina vairākas funkcijas:

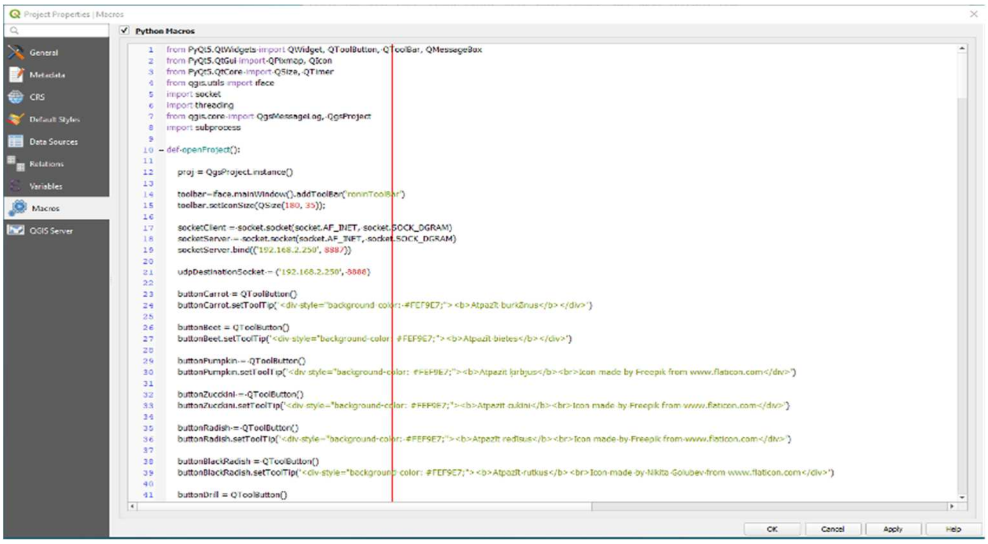
- robota darba vides ģeogrāfiskās kartes attēlošana (ortofoto attēli);
- vadības komandu nosūtīšana uz robotu;
- atgriezeniskās saistes saņemšana no borta datora;

Par pamatu grafiskajai saskarnei tika izvēlēta atvērtā koda programma QGIS, kas nodrošina ģeogrāfiskās informācijas sistēmas principus – ģeogrāfisko objektu definēšana un attēlošana kartē (skatīt 116. att).



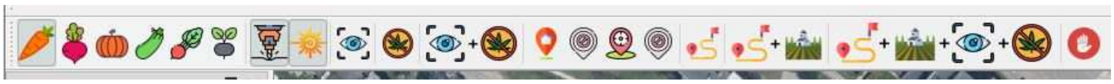
116. att. Robota vadības grafiskā saskarne QGIS programmā.

QGIS paredz iespēju izstrādāt papildus funkcionalitāti pēc lietotāja vajadzībām Python programmēšanas valodā. Viens no veidiem ir Python makrosa izveidošana, kurš izpildās QGIS projekta ielādēšanas brīdī (skatīt 117. att.).



117. att. Python makrosa izstrādes logs QGIS programmas konfigurēšanas sadaļā.

Python makrosā tika izstrādāta savstarpējā planšetes-robota komunikācija un papildus vadības pogas ar vadības loģiku, kuras tiek attēlotas QGIS grafiskajā saskarnē (skatīt 118. att).



118. att. **Robota vadības pogas (no kreisās uz labo pusi):** 1) izvēlēties burkānu, 2) izvēlēties bieti, 3) izvēlēties ķirbi, 4) izvēlēties cukini, 5) izvēlēties redīsu, 6) izvēlēties rutku, 7) izvēlēties mehānisko ierobežotāju, 8) izvēlēties lāzeru, 9) atpazīt izvēlēto kultūraugu, 10) ierobežot nezāles ar iepriekš izvēlētajiem rīkiem, 11) atpazīt izvēlēto kultūraugu un ierobežot nezāles ar iepriekš izvēlētajiem rīkiem, 12) pievienot GPS punktu maršrutam, 13) izdzēst GPS maršrutu, 14) pievienot GPS punktu vagai, 15) izdzēst GPS vagas maršrutu, 16) braukt pa maršrutu, 17) sekot vagām, 18) sekot vagām, atpazīt izvēlēto kultūraugu un ierobežot nezāles ar iepriekš izvēlētajiem rīkiem, 19) robota apturēšana.

Vadības komandu nosūtīšanu uz robotu tika realizēta caur UDP komunikācijas protokolu (skatīt 119. att.).

119. att. Planšetes-robota komunikācijas diagramma.

Planšetes grafiskās saskarnes Python makrosa kods un robota uz planšeti sūtīto attēlu atspoguļošanas skripta kods ir atrodams attiecīgi 1. pielikumā un 2. pielikumā.

Pogas nodrošina sekojošu robota funkcionalitāti un komandu izpildes scenārijus:

- pogas 1.-6. ļauj izvēlēties kultūraugu, kas atpzīšanas sistēmai jādetektē;
- pogas 7 un 8 ļauj izvēlēties robota nezāļu ierobežošanas iekārtu (mehānisko ierobežotāju vai lāzeru);
- poga 9 iedarbina robota augu atpazinēju un rezultāts tiek attēlots uz planšetes ekrāna;
- 10 poga iedarbina attiecīgo nezāļu ierobežošanas rīku;
- 11 poga veic pilnu nezāļu atpazīšanas un ierobežošanas ciklu, attēlojot rezultātus planšetē;
- ar 12.-15. pogai sastāda robota braukšanas maršrutus pa lauku un vagu;
- 16. poga iedarbina robota došanos uz lauku režīmu;
- 17. poga iedarbina robota vagas izstaigāšanu bez nezāļu ierobežošanas;
- 18. poga iedarbina robota vagas izstaigāšanu ar nezāļu ierobežošanas;
- 19. poga apstādina iepriekš sākto procesu.

120. att. Darbam sagatavots nezāļu ierobežošanas iekārtas prototips

Pēc iekārtas izgatavošanas pabeigšanas, tika turpināts darbs pie atsevišķu elementu darbības mehānisko un elektronisko kļūmju novēršanas, kā arī programmatūras atkļūdošanas.

5.4. Robota testēšana lauka apstākļos

Pēc robota izgatavošanas tas sākotnēji tika testēts Agrihorta teritorijā. Pēc tam, kad tika sasniegta stabila robota darbība, testi tika turpināti lauka apstākļos.

121. att. Mehāniskā nezāļu ierobežošanas rīka darbība lauka apstākļos

122. att. Lāzera nezāļu ierobežošanas rīka darbība lauka apstākļos

Pēc sākotnējiem lauka testiem līdz pat projekta beigām tika turpināts darbs pie mehānisko elementu darbības uzlabošanas, augu atpazinēja precizitātes uzlabošanas un programmatūras atkļūdošanas.

Lauka testus plānots turpināt pēc projekta pabeigšanas, lai iegūtu informāciju par apstrādāto nezāļu izdzīvošanu uz lauka dažādos apkārtējās vides apstākļos. Tā kā prototipa lauka testi pamatā notika rudenī, bija iespējams novērtēt tūlītējo iedarbību uz augiem, bet ne ilgtermiņa ietekmi, jo augu attīstība jau bija izmainīta dēļ laikapstākļiem.

Lāzera apstrāde

Lāzera apstrādei bija labs efekts uz divdīgļlapju nezālēm dīgļlapu un 2-6 īsto lapu attīstības stadijās - lāzera apstrādes vietās augs mainīja krāsu, nekrotizējās vai tika pilnībā pārgriezts. Netika novērota būtiska vēja ietekme uz apstrādāšanas kvalitāti, bet vēja iedarbībā augi maina atrašanās vietu, salīdzinot ar to, ko aprēķinājis atpazīšanas algoritms, kas savukārt mazina iedarbības precizitāti.

Mehāniskā apstrāde

Lielākām nezālēm (atpazīšanas algoritma rāmītis lielāks par 14cm^2), piemērotāka ir mehāniskā apstrāde. Projekta ietvaros tika testēti vairāki rotējoši uzgaļi. Konkrētā uzgaļa veida izmantošana un efektivitāte ir atkarīga no augsnes struktūras un nezāles attīstības stadijas. Uzgalis ar pīķveida zariem labi iedarbojas uz nezālēm ar platām lapām un salīdzinoši tieviem lapu kātiem vai ložņājošām nezālēm, piem., gārsa, ložņu gundega – nezāles tiek aptītas ap uzgali, izrautas un nokrīt augsnes virskārtā. Blīvākā augsnē vai nezālēm ar izteiktu mietsakni, labi darbojas arī metāla saru uzgalis – nezāles centrālā daļa ar sakni tiek sasmalcināta. Plānots, ka vajadzības gadījumā var izstrādāt vēl papildus uzgaļus, pielāgotus konkrētiem kultūraugiem.

Mobilā platforma

Mobilā platforma labi tika galā ar pārvietošanos pa dažāda slīpuma un reljefa laukiem. Katra riteņa neatkarīga piedziņa nodrošina nepieciešamo pārgājamību. Ņemot vērā to, ka platformas kopējā masa pārsniedz 100 kg, lietainā laikā uz mālainas augsnes tika novērota platformas iegrimšana un buksēšana. Lai to uzlabotu, plānots strādāt pie tā, lai palielinātu riteņu atbalsta laukumu.

Projekta ietvaros izstrādātais prototips un tā testēšana iesaistījās saimniecībās, kā arī pie citiem interesentiem sniedz vairākus būtiskus ieguvumus. Pirmkārt, saimniecībām ir iespēja strādāt pie ilgtermiņa risinājumu sev būtiskai problēmai – šajā gadījumā, nezāļu ierobežošanai tuvam kultūraugam. Pat ja pirmais prototips neatrisina visus sākotnējos tehniskos izaicinājumus, tas ir būtisks solis, lai šāda iekārta nonāktu ražošanā un būtu pieejama zemniekiem. Otrkārt, ražotājiem ir iespēja iepazīt un testēt savā saimniecībā tehnoloģijas, kuras ir jaunums visur pasaulē (lāzerravēšana, autonomie lauksaimniecības roboti), tādā veidā radot būtisku priekšnosacījumu, ātrai šo tehnoloģiju ieviešanai savās saimniecībās, tiklīdz risinājumi būs pieejami Latvijas tirgū. Treškārt, zinātniekiem un inženieriem šādu projektu ietvaros ir iespēja saņemt tiešu atgriezenisko saiti no zemniekiem, par piedāvāto risinājumu atbilstību to vajadzībām, kā arī pārbaudīt uz lauka, izstrādāto risinājumu funkcionalitāti. Savukārt zemniekiem ir iespēja saņemt informāciju no zinātniekiem par jaunākajiem pētījumu rezultātiem un citiem izstrādātajiem risinājumiem konkrētajā jomā pasaulē, kas citādi būtu grūti atrodama.

Secinājumi un nākotnes perspektīva

Robotu izmantošana lauksaimniecībā paliek arvien izplatītāka visā pasaulē. Viens no lielākajiem lauksaimniecības robotu ražotājiem paziņoja, ka saņēmis nepieciešamos saskaņojumus, lai arī Eiropā viņu ražojumi drīkstētu pārvietoties pa laukiem autonomi. Līdz ar to projektā izstrādātais prototips un iegūtās atziņas ir ļoti aktuālas.

Projekta ietvaros veikts būtisks izstrādes darbs sadarbojoties zinātniskajām institūcijām un zemniekus saimniecībām. Projekta rezultātā izstrādāts funkcionējošs robota prototips, kas spēj autonomi veikt maršrutu līdz laukam, virzīties pa kultūrauga rindu, atpazīt un iznīcināt nezāles ar mehānisko rīku vai lāzeru. Projekta eksperimentu rezultāti, iegūtie dati un izstrādātie risinājumi ir publiski pieejami šajā pārskatā norādītajās interneta vietnēs, pielikumos vai sazinoties ar projekta īstenotājiem.

Izstrādātais robota prototips īsteno tam paredzētās funkcijas, un prototipa testēšana lauka apstākļos tiks turpināta 2021. gadā, lai iegūtu rezultātus par apstrādāto nezāļu izdzīvošanu ilgstošākā periodā. Tāpat tiks turpinātāka aktīva sadarbība ar saimniecībām, lai iegūtu papildu informāciju par robota funkcionalitāti no lietotāja skatupunkta.

Turpmākajos robota izstrādes posmos akcents būtu jāliek uz izstrādātā augu atpazīšanas algoritma precizitātes uzlabošanu un papildu kultūraugu iekļaušanu, ko iespējams panākt, palielinot anotēto attēlu kopu, kā arī papildinot ar kultūraugiem ar dažādu augsnes fonu. No tehniskajiem risinājumiem papildus būtu nepieciešams izstrādāt drošības barjeru, kas aizturētu lāzera staru pēc nejaušas atstarošanās un vienlaikus netraucētu robota kustībai. Tāpat nepieciešams izstrādāt lāzera lēcas aizsargu pret putekļiem un degšanas produktiem. Lai palielinātu iekārtas ražīgumu, limitējošs faktors ir lāzera jauda, līdz ar to turpmākajā izstrādē būtu jātestē lielākas jaudas lāzeri.

No lietošanas perspektīvas, savukārt būtu svarīgi noskaidrot, vai robotam nepieciešami abi rīki – gan lāzers, gan mehāniskais, vai pietiek ar vienu, jo tas būtiski vienkāršotu robota konstrukciju. Tāpat būtiski būtu novērtēt mobilās platformas pielietošanu citām funkcijām, kas svarīgas saimniecībās, piemēram, nelielu kravu (kastes ar gatavo produkciju) pārvietošanai, rindstarpu rušināšanai u.c.

Sagatavotās publikācijas, raksti un dalība pasākumos

Projekta ietvaros sagatavotas divas zinātniskās publikācijas, kas indeksētas SCOPUS datu bāzē:

- Sudars, K., Jasko, J., Namatevs I., Ozola L., Badaukis, N. (2020). Dataset of annotated food crops and weed images for robotic computer vision control, Data in Brief, 31. doi:10.1016/j.dib.2020.105833
- Osadčuks V. Kostromins A., Pecka A., Koteļeņecs V., Jaško J. (2020) Experimental efficiency evaluation of 445 nm semiconductor laser for robotized weed control applications. Agronomy Research. Vol. 18(S2), pp. 1380-1387.

Projekta izstrādes prezentētas dažādos pasākumos:

- LLU zinātnieku naktī 2019. gada 27. septembrī;
- Izstādē "TechIndustrie 2019" Ķīpsalā no 28. līdz 30. novembrim;
- Izstādē "Skola 2020" Ķīpsalā, no 26. līdz 28. februārim;
- Tehnikas un inovāciju festivālā "Mehatrons 2020", Jelgavā, 5. septembrī;
- Izstādē "Riga COMM 2020" Ķīpsalā, 15. un 16. oktobrī.

Par projektu un izstrādāto nezāļu ierobežošanas robotu ir publicēti raksti dažādos lauksaimniecības nozares izdevumos, presē un citos medijos:

- TV sižets raidījumā Panorāma 17.10.2020 - https://www.lsm.lv/raksts/dzive--stils/tehnologijas-un-zinatne/lauksaimniecibas-universitate-radits-nezalu-ravesanas-robots-robis.a378359/
- Raksts ziņu portālā TVNet 20.10.2020 - https://www.tvnet.lv/7089267/latvijas-petnieki-rada-nezalu-ravesanas-robotu
- Raksts ziņu portālā Delfi 23.10.2020 - https://www.delfi.lv/majadarzs/aktuali/bez-sabojata-brivlaika-latviesu-zinatnieki-radijusi-ravesanas-robotu-un-mekle-razotajus.d?id=52586413
- Raksts elektroniskā žurnāla Profesionālā dārzkopība 13. numurā 2020. gada novembrī (16. pielikums)
- Sižets BBC Russia ziņu aģentūrā 07.12.2020. - https://www.bbc.com/russian/media-55220110?fbclid=IwAR1urCTvTsUaqubxIcJjlLhQ7pFNrNnes6GjOyBjr8EoXGIYciPLqJK2AlQ
- Raksts laikraksta Latvijas Avīze 2020. gada 14. decembra numurā (17. pielikums)
- Raksts žurnāla AgroTops 2021. gada janvāra numurā (18. pielikums)
- Raksts žurnāla Saimnieks 2021. gada februāra numurā (19. pielikums)

Projekta ietvaros organizētas 3 lauku dienas:

Lauku diena 2020. gada 3. septembrī pie projekta partnera ZS "Atvases"

Lauku diena 2020. gada 4. septembrī pie projekta partnera SIA "Lejasvagaļu dārzs"

Lauku diena 2020. gada 4. septembrī projekta partnera J. Lipska saimniecībā "Absolūts Ēd"

1. pielikums

QGIS Python makross

```
from PyQt5.QtWidgets import QWidget, QToolButton, QToolBar, QMessageBox
from PyQt5.QtGui import QPixmap, QIcon
from PyQt5.QtCore import QSize, QTimer
from qgis.utils import iface
import socket
import threading
from qgis.core import QgsMessageLog, QgsProject
import subprocess

def openProject():

    proj = QgsProject.instance()

    toolbar=iface.mainWindow().addToolBar('roninToolBar')
    toolbar.setIconSize(QSize(180, 35));

    socketClient = socket.socket(socket.AF_INET, socket.SOCK_DGRAM)
    socketServer = socket.socket(socket.AF_INET, socket.SOCK_DGRAM)

    #socketServer.bind(('127.0.0.1', 8887))
    socketServer.bind(('192.168.4.144', 8887))
    udpDestinationSocket = ('192.168.4.130', 8886)

    buttonCarrot = QToolButton()
    buttonCarrot.setToolTip('<div style="background-color: #FEF9E7;"><b>Atpazīt burkānus</b></div>')

    buttonBeet = QToolButton()
    buttonBeet.setToolTip('<div style="background-color: #FEF9E7;"><b>Atpazīt bietes</b></div>')

    buttonPumpkin = QToolButton()
    buttonPumpkin.setToolTip('<div style="background-color: #FEF9E7;"><b>Atpazīt ķirbjus</b><br>Icon made by Freepik from www.flaticon.com</div>')

    buttonZucckini = QToolButton()
    buttonZucckini.setToolTip('<div style="background-color: #FEF9E7;"><b>Atpazīt cukīni</b><br>Icon made by Freepik from www.flaticon.com</div>')

    buttonRadish = QToolButton()
    buttonRadish.setToolTip('<div style="background-color: #FEF9E7;"><b>Atpazīt redīsus</b><br>Icon made by Freepik from www.flaticon.com</div>')

    buttonBlackRadish = QToolButton()
    buttonBlackRadish.setToolTip('<div style="background-color: #FEF9E7;"><b>Atpazīt rutkus</b><br>Icon made by Nikita Golubev from www.flaticon.com</div>')

    buttonDrill = QToolButton()
    buttonDrill.setToolTip('<div style="background-color: #FEF9E7;"><b>Izvēlēties mehānisko ierobežotāju</b><br>Icon made by Freepik from www.flaticon.com</div>')

    buttonLaser = QToolButton()
    buttonLaser.setToolTip('<div style="background-color: #FEF9E7;"><b>Izvēlēties lāzerierobežotāju</b><br>Icon made by Freepik from www.flaticon.com</div>')

    buttonStartObjectDetection = QToolButton()
    buttonStartObjectDetection.setToolTip('<div style="background-color: #FEF9E7;"><b>Veikt augu atpazīšanu</b><br>Icon made by Freepik from www.flaticon.com</div>')

    buttonStartWeeding = QToolButton()
    buttonStartWeeding.setToolTip('<div style="background-color: #FEF9E7;"><b>Veikt nezāļu ierobežošanu</b><br>Icon made by photo3idea_studio from www.flaticon.com</div>')
```

```
    buttonStartObjectDetectionAndWeeding = QToolButton()
    buttonStartObjectDetectionAndWeeding.setToolTip('<div style="background-color: #FEF9E7;"><b>Veikt augu atpazīšanu un nezāļu ierobežošanu</b><br>Icon made by Freepik and photo3idea_studio from www.flaticon.com</div>')

    buttonAddGpsPointToRoute = QToolButton()
    buttonAddGpsPointToRoute.setToolTip('<div style="background-color: #FEF9E7;"><b>Pievienot GPS punktu maršrutam</b><br>Icon made by Freepik from www.flaticon.com</div>')

    buttonResetGpsRoute = QToolButton()
    buttonResetGpsRoute.setToolTip('<div style="background-color: #FEF9E7;"><b>Izdzēst GPS maršrutu</b><br>Icon made by Freepik from www.flaticon.com</div>')

    buttonAddGpsPointToRidge = QToolButton()
    buttonAddGpsPointToRidge.setToolTip('<div style="background-color: #FEF9E7;"><b>Pievienot GPS punktu vagai</b><br>Icon made by Freepik from www.flaticon.com</div>')

    buttonResetGpsRidge = QToolButton()
    buttonResetGpsRidge.setToolTip('<div style="background-color: #FEF9E7;"><b>Izdzēst GPS vagas maršrutu</b><br>Icon made by Freepik from www.flaticon.com</div>')

    buttonStartGpsRoute = QToolButton()
    buttonStartGpsRoute.setToolTip('<div style="background-color: #FEF9E7;"><b>Braukt pēc GPS</b><br>Icon made by Freepik from www.flaticon.com</div>')

    buttonStartGpsRouteAndFollowRow = QToolButton()
    buttonStartGpsRouteAndFollowRow.setToolTip('<div style="background-color: #FEF9E7;"><b>Braukt pēc GPS un sekot vagai</b><br>Icon made by Freepik and Flat Icons from www.flaticon.com</div>')

    buttonStartGpsRouteAndFollowRowAndObjectDetectionAndWeeding = QToolButton()
    buttonStartGpsRouteAndFollowRowAndObjectDetectionAndWeeding.setToolTip('<div style="background-color: #FEF9E7;"><b>Braukt pēc GPS, sekot vagai, atpazīt augus un ierobežot nezāles</b><br>Icon made by Freepik, Flat Icons and photo3idea_studio from www.flaticon.com</div>')

    buttonEmergencyStop = QToolButton()
    buttonEmergencyStop.setToolTip('<div style="background-color: #FEF9E7;"><b>Avārijas apstāšanās</b></div>')

    buttonStartWeeding.setEnabled(False)
    buttonStartObjectDetectionAndWeeding.setEnabled(False)
    buttonStartGpsRouteAndFollowRowAndObjectDetectionAndWeeding.setEnabled(False)

    def detectCarrots():
        proj.writeEntry('RONIN', 'detectionMode', 'burkans')
        buttonCarrot.setStyleSheet('background-color: #D5DBDB; border: 1px solid #A6ACAF; border-radius: 3px; width: 27px;')
        buttonBeet.setStyleSheet('background-color: #F2F4F4; width: 24px;')
        buttonPumpkin.setStyleSheet('background-color: #F2F4F4; width: 24px;')
        buttonZucckini.setStyleSheet('background-color: #F2F4F4; width: 24px;')
        buttonRadish.setStyleSheet('background-color: #F2F4F4; width: 24px;')
        buttonBlackRadish.setStyleSheet('background-color: #F2F4F4; width: 24px;')
        #socketClient.sendto(b'burkans', ('127.0.0.1', 8888))

    def detectBeets():
        proj.writeEntry('RONIN', 'detectionMode', 'biete')
        buttonCarrot.setStyleSheet('background-color: #F2F4F4; width: 24px;')
        buttonBeet.setStyleSheet('background-color: #D5DBDB; border: 1px solid #A6ACAF; border-radius: 3px; width: 27px;')
        buttonPumpkin.setStyleSheet('background-color: #F2F4F4; width: 24px;')
        buttonZucckini.setStyleSheet('background-color: #F2F4F4; width: 24px;')
        buttonRadish.setStyleSheet('background-color: #F2F4F4; width: 24px;')
        buttonBlackRadish.setStyleSheet('background-color: #F2F4F4; width: 24px;')
        #socketClient.sendto(detectionMode.encode(), ('127.0.0.1', 8888))

    def detectPumpkins():
        proj.writeEntry('RONIN', 'detectionMode', 'kirbis')
        buttonCarrot.setStyleSheet('background-color: #F2F4F4; width: 24px;')
        buttonBeet.setStyleSheet('background-color: #F2F4F4; width: 24px;')
        buttonPumpkin.setStyleSheet('background-color: #D5DBDB; border: 1px solid #A6ACAF; border-radius: 3px; width: 27px;')
        buttonZucckini.setStyleSheet('background-color: #F2F4F4; width: 24px;')
        buttonRadish.setStyleSheet('background-color: #F2F4F4; width: 24px;')
        buttonBlackRadish.setStyleSheet('background-color: #F2F4F4; width: 24px;')
        #socketClient.sendto(b'kirbis', ('127.0.0.1', 8888))
```

```
def detectZucchini():
    proj.writeEntry('RONIN', 'detectionMode', 'cukini')
    buttonCarrot.setStyleSheet('background-color: #F2F4F4; width: 24px;')
    buttonBeet.setStyleSheet('background-color: #F2F4F4; width: 24px;')
    buttonPumpkin.setStyleSheet('background-color: #F2F4F4; width: 24px;')
    buttonZucckini.setStyleSheet('background-color: #D5DBDB; border: 1px solid #A6ACAF; border-radius: 3px; width: 27px;')
    buttonRadish.setStyleSheet('background-color: #F2F4F4; width: 24px;')
    buttonBlackRadish.setStyleSheet('background-color: #F2F4F4; width: 24px;')
    #socketClient.sendto(b'cukini', ('127.0.0.1', 8888))

def detectRadishes():
    proj.writeEntry('RONIN', 'detectionMode', 'rediss')
    buttonCarrot.setStyleSheet('background-color: #F2F4F4; width: 24px;')
    buttonBeet.setStyleSheet('background-color: #F2F4F4; width: 24px;')
    buttonPumpkin.setStyleSheet('background-color: #F2F4F4; width: 24px;')
    buttonZucckini.setStyleSheet('background-color: #F2F4F4; width: 24px;')
    buttonRadish.setStyleSheet('background-color: #D5DBDB; border: 1px solid #A6ACAF; border-radius: 3px; width: 27px;')
    buttonBlackRadish.setStyleSheet('background-color: #F2F4F4; width: 24px;')
    #socketClient.sendto(b'rediss', ('127.0.0.1', 8888))

def detectBlackRadishes():
    proj.writeEntry('RONIN', 'detectionMode', 'rutks')
    buttonCarrot.setStyleSheet('background-color: #F2F4F4; width: 24px;')
    buttonBeet.setStyleSheet('background-color: #F2F4F4; width: 24px;')
    buttonPumpkin.setStyleSheet('background-color: #F2F4F4; width: 24px;')
    buttonZucckini.setStyleSheet('background-color: #F2F4F4; width: 24px;')
    buttonRadish.setStyleSheet('background-color: #F2F4F4; width: 24px;')
    buttonBlackRadish.setStyleSheet('background-color: #D5DBDB; border: 1px solid #A6ACAF; border-radius: 3px; width: 27px;')
    #socketClient.sendto(b'rutks', ('127.0.0.1', 8888))

def selectDrill():
    drillSelected, type_conversion_ok = proj.readBoolEntry('RONIN', 'drillSelected', False)

    if drillSelected:
        proj.writeEntry('RONIN', 'drillSelected', False)
        buttonDrill.setStyleSheet('background-color: #F2F4F4; width: 24px;')

        laserSelected, type_conversion_ok = proj.readBoolEntry('RONIN', 'laserSelected', False)
        if not laserSelected:
            buttonStartWeeding.setEnabled(False)
            buttonStartObjectDetectionAndWeeding.setEnabled(False)
            buttonStartGpsRouteAndFollowRowAndObjectDetectionAndWeeding.setEnabled(False)
    else:
        proj.writeEntry('RONIN', 'drillSelected', True)
        buttonDrill.setStyleSheet('background-color: #D5DBDB; border: 1px solid #A6ACAF; border-radius: 3px; width: 27px;')

        buttonStartWeeding.setEnabled(True)
        buttonStartObjectDetectionAndWeeding.setEnabled(True)
        buttonStartGpsRouteAndFollowRowAndObjectDetectionAndWeeding.setEnabled(True)

def selectLaser():
    laserSelected, type_conversion_ok = proj.readBoolEntry('RONIN', 'laserSelected', False)

    if laserSelected:
        proj.writeEntry('RONIN', 'laserSelected', False)
        buttonLaser.setStyleSheet('background-color: #F2F4F4; width: 24px;')

        drillSelected, type_conversion_ok = proj.readBoolEntry('RONIN', 'drillSelected', False)
        if not drillSelected:
            buttonStartWeeding.setEnabled(False)
            buttonStartObjectDetectionAndWeeding.setEnabled(False)
            buttonStartGpsRouteAndFollowRowAndObjectDetectionAndWeeding.setEnabled(False)
    else:
        proj.writeEntry('RONIN', 'laserSelected', True)
        buttonLaser.setStyleSheet('background-color: #D5DBDB; border: 1px solid #A6ACAF; border-radius: 3px; width: 27px;')

        buttonStartWeeding.setEnabled(True)
        buttonStartObjectDetectionAndWeeding.setEnabled(True)
        buttonStartGpsRouteAndFollowRowAndObjectDetectionAndWeeding.setEnabled(True)
```

```
def startObjectDetection():
    laserSelected, type_conversion_ok = proj.readBoolEntry('RONIN', 'laserSelected', False)
    drillSelected, type_conversion_ok = proj.readBoolEntry('RONIN', 'drillSelected', False)
    detectionMode, type_conversion_ok = proj.readEntry('RONIN', 'detectionMode', 'burkans')

    socketClient.sendto((f'atpazinejs,{detectionMode},laserSelected:{laserSelected},drillSelected:{drillSelected}').encode(),
udpDestinationSocket)
    #socketClient.sendto(('atpazinejs,%s' % detectionMode).encode(), udpDestinationSocket)

def startWeeding():
    laserSelected, type_conversion_ok = proj.readBoolEntry('RONIN', 'laserSelected', False)
    drillSelected, type_conversion_ok = proj.readBoolEntry('RONIN', 'drillSelected', False)

    socketClient.sendto((f'ravetajs,laserSelected:{laserSelected},drillSelected:{drillSelected}').encode(), udpDestinationSocket)

def startObjectDetectionAndWeeding():
    detectionMode, type_conversion_ok = proj.readEntry('RONIN', 'detectionMode', 'burkans')
    laserSelected, type_conversion_ok = proj.readBoolEntry('RONIN', 'laserSelected', False)
    drillSelected, type_conversion_ok = proj.readBoolEntry('RONIN', 'drillSelected', False)

    socketClient.sendto((f'atpazinejs,{detectionMode},ravetajs,laserSelected:{laserSelected},drillSelected:{drillSelected}').encode(),
udpDestinationSocket)

def startGpsRoute():
    socketClient.sendto(b'gps_marsruts', udpDestinationSocket)

def startGpsRouteAndFollowRow():
    socketClient.sendto(b'gps_marsruts,vaga', udpDestinationSocket)

def startGpsRouteAndFollowRowAndObjectDetectionAndWeeding():
    detectionMode, type_conversion_ok = proj.readEntry('RONIN', 'detectionMode', 'burkans')
    laserSelected, type_conversion_ok = proj.readBoolEntry('RONIN', 'laserSelected', False)
    drillSelected, type_conversion_ok = proj.readBoolEntry('RONIN', 'drillSelected', False)

socketClient.sendto((f'gps_marsruts,vaga,atpazinejs,{detectionMode},ravetajs,laserSelected:{laserSelected},drillSelected:{drillSelected}').encod
e(), udpDestinationSocket)

def emergencyStop():
    socketClient.sendto(b'stop', udpDestinationSocket)

def openResult(commandArgument):
    process = subprocess.Popen(f'python3 openResults.py {commandArgument}', shell=True)

def addGpsPointToRoute():
    socketClient.sendto(b'pievienot_gps_marsruta_punktu', udpDestinationSocket)

def resetGpsRoute():
    socketClient.sendto(b'izdzest_gps_marsrutu', udpDestinationSocket)

def addGpsPointToRidge():
    socketClient.sendto(b'pievienot_gps_vagas_punktu', udpDestinationSocket)

def resetGpsRidge():
    socketClient.sendto(b'izdzest_gps_vagu', udpDestinationSocket)

detectionMode, type_conversion_ok = proj.readEntry('RONIN', 'detectionMode', 'burkans')
if type_conversion_ok:
    if detectionMode == 'burkans':
        detectCarrots()
    elif detectionMode == 'biete':
        detectBeets()
    elif detectionMode == 'kirbis':
        detectPumpkins()
    elif detectionMode == 'cukini':
        detectZucchini()
    elif detectionMode == 'rediss':
        detectRadishes()
    elif detectionMode == 'rutks':
        detectBlackRadishes()
```

```
laserSelected, type_conversion_ok = proj.readBoolEntry('RONIN', 'laserSelected', False)
if type_conversion_ok:
    if laserSelected:
        selectLaser()

        timer = QTimer()
        timer.setSingleShot(True)
        timer.singleShot(500, selectLaser)

drillSelected, type_conversion_ok = proj.readBoolEntry('RONIN', 'drillSelected', False)
if type_conversion_ok:
    if drillSelected:
        selectDrill()

        timer = QTimer()
        timer.setSingleShot(True)
        timer.singleShot(500, selectDrill)

class udpServerThread (threading.Thread):
    def __init__(self):
        threading.Thread.__init__(self)
        self.stop_event = threading.Event()
    def run(self):
        while not self.stop_event.is_set():
            QgsMessageLog.logMessage('gaida UDP ziņojumu', 'RONIN', 0)
            data, addr = socketServer.recvfrom(1024) # buffer size is 1024 bytes

            message = data.decode('utf-8')

            if message == 'komanda sanemta':
                QgsMessageLog.logMessage(f'ienākošais UDP ziņojums: {message}', 'RONIN', 0)
                #QMessageBox.information(None, 'Informācija', 'Komanda nosūtīta veiksmīgi')
            elif message == 'atpazisana pabeigta':
                QgsMessageLog.logMessage(f'ienākošais UDP ziņojums: {message}', 'RONIN', 0)
                openResult('detection')
            elif message == 'ierobezosana pabeigta':
                QgsMessageLog.logMessage(f'ienākošais UDP ziņojums: {message}', 'RONIN', 0)
                openResult('treatment')
            else:
                QgsMessageLog.logMessage(f'nederīgs ienākošais UDP ziņojums: {message}', 'RONIN', 0)

            self.stop_event.wait(0.1)

#poga atpazīt burkānus
buttonCarrot.clicked.connect(detectCarrots)
pixmap = QPixmap('icons/carrot.png')
buttonCarrot.setIcon(QIcon(pixmap))
toolbar.addWidget(buttonCarrot)

#poga atpazīt bietes
buttonBeet.clicked.connect(detectBeets)
pixmap = QPixmap('icons/beet.png')
buttonBeet.setIcon(QIcon(pixmap))
toolbar.addWidget(buttonBeet)

#poga atpazīt ķirbi
buttonPumpkin.clicked.connect(detectPumpkins)
pixmap = QPixmap('icons/pumpkin.png')
buttonPumpkin.setIcon(QIcon(pixmap))
toolbar.addWidget(buttonPumpkin)

#poga atpazīt cukīni
buttonZucckini.clicked.connect(detectZucchini)
pixmap = QPixmap('icons/zucchini.png')
buttonZucckini.setIcon(QIcon(pixmap))
toolbar.addWidget(buttonZucckini)

#poga atpazīt redisu
buttonRadish.clicked.connect(detectRadishes)
```

```
pixmap = QPixmap('icons/radish.png')
buttonRadish.setIcon(QIcon(pixmap))
toolbar.addWidget(buttonRadish)

#poga atpazīt rutku
buttonBlackRadish.clicked.connect(detectBlackRadishes)
pixmap = QPixmap('icons/radish_black.png')
buttonBlackRadish.setIcon(QIcon(pixmap))
toolbar.addWidget(buttonBlackRadish)

toolbar.addSeparator()

#poga izvēlēties urbi
buttonDrill.clicked.connect(selectDrill)
pixmap = QPixmap('icons/drill.png')
buttonDrill.setIcon(QIcon(pixmap))
buttonDrill.setStyleSheet('width: 24px')
toolbar.addWidget(buttonDrill)

#poga izvēlēties lāzeri
buttonLaser.clicked.connect(selectLaser)
pixmap = QPixmap('icons/laser.png')
buttonLaser.setIcon(QIcon(pixmap))
buttonLaser.setStyleSheet('width: 24px')
toolbar.addWidget(buttonLaser)

toolbar.addSeparator()

#poga atpazīšanai
buttonStartObjectDetection.clicked.connect(startObjectDetection)
pixmap = QPixmap('icons/eye.png')
buttonStartObjectDetection.setIcon(QIcon(pixmap))
buttonStartObjectDetection.setStyleSheet('width: 24px')
toolbar.addWidget(buttonStartObjectDetection)

toolbar.addSeparator()

#poga nezāļu ierobežošanai
buttonStartWeeding.clicked.connect(startWeeding)
pixmap = QPixmap('icons/weeding.png')
buttonStartWeeding.setIcon(QIcon(pixmap))
buttonStartWeeding.setStyleSheet('width: 24px')
toolbar.addWidget(buttonStartWeeding)

toolbar.addSeparator()

#poga atpazīšanai un nezāļu ierobežošanai
buttonStartObjectDetectionAndWeeding.clicked.connect(startObjectDetectionAndWeeding)
pixmap = QPixmap('icons/eye_plus_weeding.png')
buttonStartObjectDetectionAndWeeding.setIcon(QIcon(pixmap))
buttonStartObjectDetectionAndWeeding.setStyleSheet('width: 73px')
toolbar.addWidget(buttonStartObjectDetectionAndWeeding)

toolbar.addSeparator()

#poga GPS punkta pievienošanai maršrutam
buttonAddGpsPointToRoute.clicked.connect(addGpsPointToRoute)
pixmap = QPixmap('icons/gpsPointRoute.png')
buttonAddGpsPointToRoute.setIcon(QIcon(pixmap))
buttonAddGpsPointToRoute.setStyleSheet('width: 24px')
toolbar.addWidget(buttonAddGpsPointToRoute)

#poga GPS maršrutam izdzēšanai
buttonResetGpsRoute.clicked.connect(resetGpsRoute)
pixmap = QPixmap('icons/resetGpsRoute.png')
buttonResetGpsRoute.setIcon(QIcon(pixmap))
buttonResetGpsRoute.setStyleSheet('width: 24px')
toolbar.addWidget(buttonResetGpsRoute)

#poga GPS punkta pievienošanai vagai
```

```
            buttonAddGpsPointToRidge.clicked.connect(addGpsPointToRidge)
            pixmap = QPixmap('icons/gpsPointRidge.png')
            buttonAddGpsPointToRidge.setIcon(QIcon(pixmap))
            buttonAddGpsPointToRidge.setStyleSheet('width: 24px')
            toolbar.addWidget(buttonAddGpsPointToRidge)

            #poga GPS vagas maršrutam izdzēšanai
            buttonResetGpsRidge.clicked.connect(resetGpsRidge)
            pixmap = QPixmap('icons/resetGpsRoute.png')
            buttonResetGpsRidge.setIcon(QIcon(pixmap))
            buttonResetGpsRidge.setStyleSheet('width: 24px')
            toolbar.addWidget(buttonResetGpsRidge)

            toolbar.addSeparator()

            #poga braukšanai pēc GPS maršruta
            buttonStartGpsRoute.clicked.connect(startGpsRoute)
            pixmap = QPixmap('icons/route.png')
            buttonStartGpsRoute.setIcon(QIcon(pixmap))
            buttonStartGpsRoute.setStyleSheet('width: 24px')
            toolbar.addWidget(buttonStartGpsRoute)

            toolbar.addSeparator()

            #poga braukšanai pēc GPS maršruta un sekošana vagai
            buttonStartGpsRouteAndFollowRow.clicked.connect(startGpsRouteAndFollowRow)
            pixmap = QPixmap('icons/route_plus_row.png')
            buttonStartGpsRouteAndFollowRow.setIcon(QIcon(pixmap))
            buttonStartGpsRouteAndFollowRow.setStyleSheet('width: 73px')
            toolbar.addWidget(buttonStartGpsRouteAndFollowRow)

            toolbar.addSeparator()

            #poga braukšanai pēc GPS maršruta, sekošana vagai, atpazīšana un nezāļu ierobežošana

buttonStartGpsRouteAndFollowRowAndObjectDetectionAndWeeding.clicked.connect(startGpsRouteAndFollowRowAndObjectDetectionAndW
eeding)
            pixmap = QPixmap('icons/route_plus_row_plus_eye_plus_weeding.png')
            buttonStartGpsRouteAndFollowRowAndObjectDetectionAndWeeding.setIcon(QIcon(pixmap))
            toolbar.addWidget(buttonStartGpsRouteAndFollowRowAndObjectDetectionAndWeeding)

            toolbar.addSeparator()

            #poga avārijas apstāšanās
            buttonEmergencyStop.clicked.connect(emergencyStop)
            pixmap = QPixmap('icons/stop.png')
            buttonEmergencyStop.setIcon(QIcon(pixmap))
            buttonEmergencyStop.setStyleSheet('width: 24px')
            toolbar.addWidget(buttonEmergencyStop)

            udpServer = udpServerThread()
            udpServer.daemon = True
            udpServer.start()

            pass

        def saveProject():
            pass

        def closeProject():
            pass
```

2. pielikums

openResults.py skripts robota sūtīto attēlu atspoguļošanai

```
import sys
from PyQt5.QtWidgets import QApplication, QMainWindow, QLabel, QGridLayout, QWidget, QMessageBox
from PyQt5.QtGui import QPixmap
import os.path

class Viewer(QWidget):

    def __init__(self, path, title, startX, start_Y):
        super().__init__()

        self.im = QPixmap(path)
        self.label = QLabel()
        self.label.setPixmap(self.im)

        self.grid = QGridLayout()
        self.grid.addWidget(self.label,1,1)
        self.setLayout(self.grid)

        self.setGeometry(startX,start_Y,300,300)
        self.setWindowTitle(title)
        self.show()

if __name__ == '__main__':
    app = QApplication(sys.argv)

    if sys.argv[1] == 'detection':
        #if os.path.isfile("//RONIN-DESKTOP/shared/atpazisanas_rezultats_drill.jpg"):
        #   beforeObjectDetectionMechanical = Viewer("//RONIN-DESKTOP/shared/atpazisanas_rezultats_drill.jpg", 'Pirms atpazīšanas - mehāniskais ierobežotājs', 50, 50)
        if os.path.isfile("//RONIN-DESKTOP/shared/atpazisanas_rezultats_drill.jpg"):
            afterObjectDetectioMechanical = Viewer("//RONIN-DESKTOP/shared/atpazisanas_rezultats_drill.jpg", 'Pēc atpazīšanas - mehāniskais ierobežotājs', 600, 50)
        #if os.path.isfile("//RONIN-DESKTOP/shared/atpazisanas_rezultats_laser.jpg"):
        #    beforeObjectDetectioLaser = Viewer("//RONIN-DESKTOP/shared/atpazisanas_rezultats_laser.jpg", 'Pirms atpazīšanas - lāzers', 50, 600)
        if os.path.isfile("//RONIN-DESKTOP/shared/atpazisanas_rezultats_laser.jpg"):
            afterObjectDetectioLaser = Viewer("//RONIN-DESKTOP/shared/atpazisanas_rezultats_laser.jpg", 'Pēc atpazīšanas - lāzers', 600, 600)
    elif sys.argv[1] == 'treatment':
        if os.path.isfile("//RONIN-DESKTOP/shared/atpazisanas_rezultats_drill.jpg"):
            afterObjectDetectioMechanical = Viewer("//RONIN-DESKTOP/shared/atpazisanas_rezultats_drill.jpg", 'Pēc atpazīšanas - mehāniskais ierobežotājs', 50, 50)
        if os.path.isfile("//RONIN-DESKTOP/shared/pec_apstrades_drill.jpg"):
            afterMechanicalTreatment = Viewer("//RONIN-DESKTOP/shared/pec_apstrades_drill.jpg", 'Pēc apstrādes ar mehānisko ierobežotāju', 600, 50)
        if os.path.isfile("//RONIN-DESKTOP/shared/atpazisanas_rezultats_laser.jpg"):
            afterObjectDetectioLaser = Viewer("//RONIN-DESKTOP/shared/atpazisanas_rezultats_laser.jpg", 'Pēc atpazīšanas - lāzers', 50, 600)
        if os.path.isfile("//RONIN-DESKTOP/shared/pec_apstrades_laser.jpg"):
            afterLaserTreatment = Viewer("//RONIN-DESKTOP/shared/pec_apstrades_laser.jpg", 'Pēc apstrādes ar lāzeru', 600, 600)
    else:
        QgsMessageLog.logMessage('nederīgs arguments: %s' % sys.argv[1], 'RONIN', 0)

    sys.exit(app.exec_())
```

3. pielikums

UR10 galvenā vadības bloka kods

```
def tcp_client_v3():
 set_standard_analog_input_domain(0, 1)
 set_standard_analog_input_domain(1, 1)
 set_tool_analog_input_domain(0, 1)
 set_tool_analog_input_domain(1, 1)
 set_analog_outputdomain(0, 1)
 set_analog_outputdomain(1, 1)
 set_tool_voltage(0)
 set_input_actions_to_default()
 set_tcp(p[0.0,0.0,0.0,0.0,0.0,0.0])
 set_payload(2.0, [0.0, 0.0, 0.1])
 set_gravity([0.0, 0.0, 9.82])
 $ 1 "BeforeStart"
 $ 2 "speed≔0.01"
 global speed=0.01
 $ 3 "loop_counter≔0"
 global loop_counter=0
 $ 4 "counter≔0"
 global counter=0
 $ 5 "socket≔socket_open('192.168.80.10', 888)"
 global socket=socket_open("192.168.80.10", 888)
 $ 6 "point≔p[0,0,0,0,0,0]"
 global point=p[0,0,0,0,0,0]
 $ 7 "Script: masivsV3.script"
 m_point_0=p[0,0,0,0,0,0]
 m_point_1=p[0,0,0,0,0,0]
 m_point_2=p[0,0,0,0,0,0]
 m_point_3=p[0,0,0,0,0,0]
 m_point_4=p[0,0,0,0,0,0]
 m_point_5=p[0,0,0,0,0,0]
 m_point_6=p[0,0,0,0,0,0]
 m_point_7=p[0,0,0,0,0,0]
 m_point_8=p[0,0,0,0,0,0]
 m_point_9=p[0,0,0,0,0,0]
 m_point_10=p[0,0,0,0,0,0]
 m_point_11=p[0,0,0,0,0,0]
 m_point_12=p[0,0,0,0,0,0]
 m_point_13=p[0,0,0,0,0,0]
 m_point_14=p[0,0,0,0,0,0]
 m_point_15=p[0,0,0,0,0,0]
 m_point_16=p[0,0,0,0,0,0]
 m_point_17=p[0,0,0,0,0,0]
 m_point_18=p[0,0,0,0,0,0]
 m_point_19=p[0,0,0,0,0,0]
 m_point_20=p[0,0,0,0,0,0]
 m_point_21=p[0,0,0,0,0,0]
 m_point_22=p[0,0,0,0,0,0]
 m_point_23=p[0,0,0,0,0,0]
 m_point_24=p[0,0,0,0,0,0]
 m_point_25=p[0,0,0,0,0,0]
 m_point_26=p[0,0,0,0,0,0]
 m_point_27=p[0,0,0,0,0,0]
 m_point_28=p[0,0,0,0,0,0]
 m_point_29=p[0,0,0,0,0,0]
 m_point_30=p[0,0,0,0,0,0]
 m_point_31=p[0,0,0,0,0,0]
 m_point_32=p[0,0,0,0,0,0]
 m_point_33=p[0,0,0,0,0,0]
 m_point_34=p[0,0,0,0,0,0]
 m_point_35=p[0,0,0,0,0,0]
 m_point_36=p[0,0,0,0,0,0]
```

m_point_37=p[0,0,0,0,0,0]
m_point_38=p[0,0,0,0,0,0]
m_point_39=p[0,0,0,0,0,0]
m_point_40=p[0,0,0,0,0,0]
m_point_41=p[0,0,0,0,0,0]
m_point_42=p[0,0,0,0,0,0]
m_point_43=p[0,0,0,0,0,0]
m_point_44=p[0,0,0,0,0,0]
m_point_45=p[0,0,0,0,0,0]
m_point_46=p[0,0,0,0,0,0]
m_point_47=p[0,0,0,0,0,0]
m_point_48=p[0,0,0,0,0,0]
m_point_49=p[0,0,0,0,0,0]
m_point_50=p[0,0,0,0,0,0]
m_point_51=p[0,0,0,0,0,0]
m_point_52=p[0,0,0,0,0,0]
m_point_53=p[0,0,0,0,0,0]
m_point_54=p[0,0,0,0,0,0]
m_point_55=p[0,0,0,0,0,0]
m_point_56=p[0,0,0,0,0,0]
m_point_57=p[0,0,0,0,0,0]
m_point_58=p[0,0,0,0,0,0]
m_point_59=p[0,0,0,0,0,0]
m_point_60=p[0,0,0,0,0,0]
m_point_61=p[0,0,0,0,0,0]
m_point_62=p[0,0,0,0,0,0]
m_point_63=p[0,0,0,0,0,0]
m_point_64=p[0,0,0,0,0,0]
m_point_65=p[0,0,0,0,0,0]
m_point_66=p[0,0,0,0,0,0]
m_point_67=p[0,0,0,0,0,0]
m_point_68=p[0,0,0,0,0,0]
m_point_69=p[0,0,0,0,0,0]
m_point_70=p[0,0,0,0,0,0]
m_point_71=p[0,0,0,0,0,0]
m_point_72=p[0,0,0,0,0,0]
m_point_73=p[0,0,0,0,0,0]
m_point_74=p[0,0,0,0,0,0]
m_point_75=p[0,0,0,0,0,0]
m_point_76=p[0,0,0,0,0,0]
m_point_77=p[0,0,0,0,0,0]
m_point_78=p[0,0,0,0,0,0]
m_point_79=p[0,0,0,0,0,0]
m_point_80=p[0,0,0,0,0,0]
m_point_81=p[0,0,0,0,0,0]
m_point_82=p[0,0,0,0,0,0]
m_point_83=p[0,0,0,0,0,0]
m_point_84=p[0,0,0,0,0,0]
m_point_85=p[0,0,0,0,0,0]
m_point_86=p[0,0,0,0,0,0]
m_point_87=p[0,0,0,0,0,0]
m_point_88=p[0,0,0,0,0,0]
m_point_89=p[0,0,0,0,0,0]
m_point_90=p[0,0,0,0,0,0]
m_point_91=p[0,0,0,0,0,0]
m_point_92=p[0,0,0,0,0,0]
m_point_93=p[0,0,0,0,0,0]
m_point_94=p[0,0,0,0,0,0]
m_point_95=p[0,0,0,0,0,0]
m_point_96=p[0,0,0,0,0,0]
m_point_97=p[0,0,0,0,0,0]
m_point_98=p[0,0,0,0,0,0]
m_point_99=p[0,0,0,0,0,0]
m_point_100=p[0,0,0,0,0,0]
m_point_101=p[0,0,0,0,0,0]
m_point_102=p[0,0,0,0,0,0]
m_point_103=p[0,0,0,0,0,0]
m_point_104=p[0,0,0,0,0,0]
m_point_105=p[0,0,0,0,0,0]
m_point_106=p[0,0,0,0,0,0]

m_point_107=p[0,0,0,0,0,0]
m_point_108=p[0,0,0,0,0,0]
m_point_109=p[0,0,0,0,0,0]
m_point_110=p[0,0,0,0,0,0]
m_point_111=p[0,0,0,0,0,0]
m_point_112=p[0,0,0,0,0,0]
m_point_113=p[0,0,0,0,0,0]
m_point_114=p[0,0,0,0,0,0]
m_point_115=p[0,0,0,0,0,0]
m_point_116=p[0,0,0,0,0,0]
m_point_117=p[0,0,0,0,0,0]
m_point_118=p[0,0,0,0,0,0]
m_point_119=p[0,0,0,0,0,0]
m_point_120=p[0,0,0,0,0,0]
m_point_121=p[0,0,0,0,0,0]
m_point_122=p[0,0,0,0,0,0]
m_point_123=p[0,0,0,0,0,0]
m_point_124=p[0,0,0,0,0,0]
m_point_125=p[0,0,0,0,0,0]
m_point_126=p[0,0,0,0,0,0]
m_point_127=p[0,0,0,0,0,0]
m_point_128=p[0,0,0,0,0,0]
m_point_129=p[0,0,0,0,0,0]
m_point_130=p[0,0,0,0,0,0]
m_point_131=p[0,0,0,0,0,0]
m_point_132=p[0,0,0,0,0,0]
m_point_133=p[0,0,0,0,0,0]
m_point_134=p[0,0,0,0,0,0]
m_point_135=p[0,0,0,0,0,0]
m_point_136=p[0,0,0,0,0,0]
m_point_137=p[0,0,0,0,0,0]
m_point_138=p[0,0,0,0,0,0]
m_point_139=p[0,0,0,0,0,0]
m_point_140=p[0,0,0,0,0,0]
m_point_141=p[0,0,0,0,0,0]
m_point_142=p[0,0,0,0,0,0]
m_point_143=p[0,0,0,0,0,0]
m_point_144=p[0,0,0,0,0,0]
m_point_145=p[0,0,0,0,0,0]
m_point_146=p[0,0,0,0,0,0]
m_point_147=p[0,0,0,0,0,0]
m_point_148=p[0,0,0,0,0,0]
m_point_149=p[0,0,0,0,0,0]
m_point_150=p[0,0,0,0,0,0]
m_point_151=p[0,0,0,0,0,0]
m_point_152=p[0,0,0,0,0,0]
m_point_153=p[0,0,0,0,0,0]
m_point_154=p[0,0,0,0,0,0]
m_point_155=p[0,0,0,0,0,0]
m_point_156=p[0,0,0,0,0,0]
m_point_157=p[0,0,0,0,0,0]
m_point_158=p[0,0,0,0,0,0]
m_point_159=p[0,0,0,0,0,0]
m_point_160=p[0,0,0,0,0,0]
m_point_161=p[0,0,0,0,0,0]
m_point_162=p[0,0,0,0,0,0]
m_point_163=p[0,0,0,0,0,0]
m_point_164=p[0,0,0,0,0,0]
m_point_165=p[0,0,0,0,0,0]
m_point_166=p[0,0,0,0,0,0]
m_point_167=p[0,0,0,0,0,0]
m_point_168=p[0,0,0,0,0,0]
m_point_169=p[0,0,0,0,0,0]
m_point_170=p[0,0,0,0,0,0]
m_point_171=p[0,0,0,0,0,0]
m_point_172=p[0,0,0,0,0,0]
m_point_173=p[0,0,0,0,0,0]
m_point_174=p[0,0,0,0,0,0]
m_point_175=p[0,0,0,0,0,0]
m_point_176=p[0,0,0,0,0,0]

m_point_177=p[0,0,0,0,0,0]
m_point_178=p[0,0,0,0,0,0]
m_point_179=p[0,0,0,0,0,0]
m_point_180=p[0,0,0,0,0,0]
m_point_181=p[0,0,0,0,0,0]
m_point_182=p[0,0,0,0,0,0]
m_point_183=p[0,0,0,0,0,0]
m_point_184=p[0,0,0,0,0,0]
m_point_185=p[0,0,0,0,0,0]
m_point_186=p[0,0,0,0,0,0]
m_point_187=p[0,0,0,0,0,0]
m_point_188=p[0,0,0,0,0,0]
m_point_189=p[0,0,0,0,0,0]
m_point_190=p[0,0,0,0,0,0]
m_point_191=p[0,0,0,0,0,0]
m_point_192=p[0,0,0,0,0,0]
m_point_193=p[0,0,0,0,0,0]
m_point_194=p[0,0,0,0,0,0]
m_point_195=p[0,0,0,0,0,0]
m_point_196=p[0,0,0,0,0,0]
m_point_197=p[0,0,0,0,0,0]
m_point_198=p[0,0,0,0,0,0]
m_point_199=p[0,0,0,0,0,0]
m_point_200=p[0,0,0,0,0,0]
m_point_201=p[0,0,0,0,0,0]
m_point_202=p[0,0,0,0,0,0]
m_point_203=p[0,0,0,0,0,0]
m_point_204=p[0,0,0,0,0,0]
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m_point_939=p[0,0,0,0,0,0]
m_point_940=p[0,0,0,0,0,0]
m_point_941=p[0,0,0,0,0,0]
m_point_942=p[0,0,0,0,0,0]
m_point_943=p[0,0,0,0,0,0]
m_point_944=p[0,0,0,0,0,0]
m_point_945=p[0,0,0,0,0,0]
m_point_946=p[0,0,0,0,0,0]

```
m_point_947=p[0,0,0,0,0,0]
m_point_948=p[0,0,0,0,0,0]
m_point_949=p[0,0,0,0,0,0]
m_point_950=p[0,0,0,0,0,0]
m_point_951=p[0,0,0,0,0,0]
m_point_952=p[0,0,0,0,0,0]
m_point_953=p[0,0,0,0,0,0]
m_point_954=p[0,0,0,0,0,0]
m_point_955=p[0,0,0,0,0,0]
m_point_956=p[0,0,0,0,0,0]
m_point_957=p[0,0,0,0,0,0]
m_point_958=p[0,0,0,0,0,0]
m_point_959=p[0,0,0,0,0,0]
m_point_960=p[0,0,0,0,0,0]
m_point_961=p[0,0,0,0,0,0]
m_point_962=p[0,0,0,0,0,0]
m_point_963=p[0,0,0,0,0,0]
m_point_964=p[0,0,0,0,0,0]
m_point_965=p[0,0,0,0,0,0]
m_point_966=p[0,0,0,0,0,0]
m_point_967=p[0,0,0,0,0,0]
m_point_968=p[0,0,0,0,0,0]
m_point_969=p[0,0,0,0,0,0]
m_point_970=p[0,0,0,0,0,0]
m_point_971=p[0,0,0,0,0,0]
m_point_972=p[0,0,0,0,0,0]
m_point_973=p[0,0,0,0,0,0]
m_point_974=p[0,0,0,0,0,0]
m_point_975=p[0,0,0,0,0,0]
m_point_976=p[0,0,0,0,0,0]
m_point_977=p[0,0,0,0,0,0]
m_point_978=p[0,0,0,0,0,0]
m_point_979=p[0,0,0,0,0,0]
m_point_980=p[0,0,0,0,0,0]
m_point_981=p[0,0,0,0,0,0]
m_point_982=p[0,0,0,0,0,0]
m_point_983=p[0,0,0,0,0,0]
m_point_984=p[0,0,0,0,0,0]
m_point_985=p[0,0,0,0,0,0]
m_point_986=p[0,0,0,0,0,0]
m_point_987=p[0,0,0,0,0,0]
m_point_988=p[0,0,0,0,0,0]
m_point_989=p[0,0,0,0,0,0]
m_point_990=p[0,0,0,0,0,0]
m_point_991=p[0,0,0,0,0,0]
m_point_992=p[0,0,0,0,0,0]
m_point_993=p[0,0,0,0,0,0]
m_point_994=p[0,0,0,0,0,0]
m_point_995=p[0,0,0,0,0,0]
m_point_996=p[0,0,0,0,0,0]
m_point_997=p[0,0,0,0,0,0]
m_point_998=p[0,0,0,0,0,0]
m_point_999=p[0,0,0,0,0,0]


def get_point(pointer =0):
        if pointer == 0:
                return m_point_0
        elif pointer ==1:
 return m_point_1
 elif pointer ==2:
 return m_point_2
 elif pointer ==3:
 return m_point_3
 elif pointer ==4:
 return m_point_4
 elif pointer ==5:
 return m_point_5
 elif pointer ==6:
```

```
 return m_point_6
elif pointer ==7:
 return m_point_7
elif pointer ==8:
 return m_point_8
elif pointer ==9:
 return m_point_9
elif pointer ==10:
 return m_point_10
elif pointer ==11:
 return m_point_11
elif pointer ==12:
 return m_point_12
elif pointer ==13:
 return m_point_13
elif pointer ==14:
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elif pointer ==15:
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elif pointer ==16:
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elif pointer ==17:
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elif pointer ==18:
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elif pointer ==19:
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elif pointer ==20:
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elif pointer ==21:
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elif pointer ==22:
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elif pointer ==23:
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elif pointer ==24:
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elif pointer ==25:
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elif pointer ==26:
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elif pointer ==27:
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elif pointer ==28:
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elif pointer ==29:
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elif pointer ==31:
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elif pointer ==32:
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elif pointer ==33:
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elif pointer ==34:
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elif pointer ==35:
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elif pointer ==36:
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elif pointer ==37:
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elif pointer ==38:
 return m_point_38
elif pointer ==39:
 return m_point_39
elif pointer ==40:
 return m_point_40
elif pointer ==41:
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 return m_point_41
elif pointer ==42:
 return m_point_42
elif pointer ==43:
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elif pointer ==44:
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elif pointer ==46:
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elif pointer ==111:
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elif pointer ==286:
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elif pointer ==446:
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elif pointer ==447:
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elif pointer ==458:
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elif pointer ==459:
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elif pointer ==460:
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elif pointer ==461:
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 return m_point_461
elif pointer ==462:
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elif pointer ==463:
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elif pointer ==464:
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elif pointer ==465:
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elif pointer ==472:
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elif pointer ==473:
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elif pointer ==474:
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elif pointer ==475:
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elif pointer ==476:
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elif pointer ==477:
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elif pointer ==496:
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 return m_point_496
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  elif pointer ==500:
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elif pointer ==528:
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elif pointer ==529:
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elif pointer ==530:
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elif pointer ==531:
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 return m_point_531
elif pointer ==532:
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elif pointer ==533:
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elif pointer ==535:
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elif pointer ==563:
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elif pointer ==564:
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elif pointer ==565:
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elif pointer ==566:
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 return m_point_566
elif pointer ==567:
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elif pointer ==568:
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elif pointer ==569:
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elif pointer ==570:
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elif pointer ==571:
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elif pointer ==582:
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elif pointer ==619:
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elif pointer ==620:
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elif pointer ==621:
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elif pointer ==622:
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elif pointer ==623:
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elif pointer ==624:
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elif pointer ==626:
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elif pointer ==628:
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elif pointer ==629:
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elif pointer ==630:
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elif pointer ==631:
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elif pointer ==632:
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elif pointer ==633:
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elif pointer ==634:
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elif pointer ==635:
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elif pointer ==636:
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 return m_point_636
elif pointer ==637:
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elif pointer ==638:
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elif pointer ==639:
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elif pointer ==640:
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elif pointer ==668:
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elif pointer ==669:
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elif pointer ==670:
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elif pointer ==671:
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 return m_point_671
elif pointer ==672:
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elif pointer ==673:
 return m_point_673
elif pointer ==674:
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elif pointer ==675:
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elif pointer ==676:
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elif pointer ==698:
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elif pointer ==699:
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elif pointer ==700:
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elif pointer ==701:
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elif pointer ==702:
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elif pointer ==703:
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elif pointer ==704:
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elif pointer ==705:
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elif pointer ==706:
```

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 return m_point_706
elif pointer ==707:
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elif pointer ==708:
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elif pointer ==709:
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elif pointer ==710:
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elif pointer ==711:
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elif pointer ==712:
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elif pointer ==713:
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elif pointer ==714:
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elif pointer ==715:
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elif pointer ==716:
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elif pointer ==717:
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elif pointer ==718:
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elif pointer ==719:
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elif pointer ==720:
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elif pointer ==721:
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elif pointer ==722:
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elif pointer ==723:
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elif pointer ==724:
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elif pointer ==725:
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elif pointer ==726:
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elif pointer ==727:
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elif pointer ==728:
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elif pointer ==729:
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elif pointer ==730:
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elif pointer ==731:
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elif pointer ==732:
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elif pointer ==733:
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elif pointer ==734:
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elif pointer ==735:
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elif pointer ==736:
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elif pointer ==737:
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elif pointer ==738:
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elif pointer ==739:
 return m_point_739
elif pointer ==740:
 return m_point_740
elif pointer ==741:
```

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 return m_point_741
elif pointer ==742:
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elif pointer ==743:
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elif pointer ==744:
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elif pointer ==745:
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elif pointer ==746:
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elif pointer ==747:
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elif pointer ==748:
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elif pointer ==749:
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elif pointer ==750:
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elif pointer ==751:
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elif pointer ==752:
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elif pointer ==753:
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elif pointer ==754:
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elif pointer ==755:
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elif pointer ==756:
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elif pointer ==757:
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elif pointer ==758:
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elif pointer ==759:
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elif pointer ==760:
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elif pointer ==761:
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elif pointer ==762:
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elif pointer ==763:
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elif pointer ==764:
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elif pointer ==765:
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elif pointer ==766:
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elif pointer ==767:
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elif pointer ==768:
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elif pointer ==769:
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elif pointer ==770:
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elif pointer ==771:
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elif pointer ==772:
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elif pointer ==773:
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elif pointer ==774:
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elif pointer ==775:
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elif pointer ==776:
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 return m_point_776
elif pointer ==777:
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elif pointer ==778:
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elif pointer ==779:
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elif pointer ==780:
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elif pointer ==781:
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elif pointer ==782:
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elif pointer ==783:
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elif pointer ==784:
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elif pointer ==785:
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elif pointer ==786:
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elif pointer ==787:
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elif pointer ==788:
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elif pointer ==789:
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elif pointer ==790:
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elif pointer ==791:
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elif pointer ==792:
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elif pointer ==793:
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elif pointer ==794:
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elif pointer ==795:
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elif pointer ==796:
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elif pointer ==797:
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elif pointer ==798:
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elif pointer ==799:
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elif pointer ==800:
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elif pointer ==802:
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elif pointer ==803:
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elif pointer ==804:
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elif pointer ==805:
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elif pointer ==806:
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elif pointer ==807:
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elif pointer ==808:
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elif pointer ==809:
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elif pointer ==810:
 return m_point_810
elif pointer ==811:
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 return m_point_811
elif pointer ==812:
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elif pointer ==813:
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elif pointer ==814:
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elif pointer ==815:
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elif pointer ==816:
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elif pointer ==817:
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elif pointer ==818:
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elif pointer ==819:
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elif pointer ==820:
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elif pointer ==821:
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elif pointer ==823:
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elif pointer ==824:
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elif pointer ==825:
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elif pointer ==826:
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elif pointer ==827:
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elif pointer ==828:
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elif pointer ==829:
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elif pointer ==830:
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elif pointer ==831:
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elif pointer ==832:
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elif pointer ==833:
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elif pointer ==834:
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elif pointer ==835:
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elif pointer ==836:
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elif pointer ==837:
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elif pointer ==838:
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elif pointer ==839:
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elif pointer ==840:
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elif pointer ==841:
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elif pointer ==842:
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elif pointer ==843:
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elif pointer ==844:
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elif pointer ==845:
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elif pointer ==846:
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 return m_point_846
elif pointer ==847:
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elif pointer ==848:
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elif pointer ==849:
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elif pointer ==850:
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elif pointer ==851:
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elif pointer ==852:
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elif pointer ==862:
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elif pointer ==863:
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elif pointer ==864:
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elif pointer ==865:
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elif pointer ==866:
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elif pointer ==867:
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elif pointer ==877:
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elif pointer ==879:
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elif pointer ==880:
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elif pointer ==881:
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 return m_point_881
elif pointer ==882:
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elif pointer ==883:
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elif pointer ==884:
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elif pointer ==885:
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elif pointer ==888:
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elif pointer ==890:
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elif pointer ==896:
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elif pointer ==900:
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elif pointer ==914:
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elif pointer ==915:
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elif pointer ==916:
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 return m_point_916
elif pointer ==917:
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elif pointer ==918:
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elif pointer ==932:
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elif pointer ==934:
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elif pointer ==935:
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elif pointer ==937:
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elif pointer ==938:
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elif pointer ==939:
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elif pointer ==940:
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elif pointer ==941:
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elif pointer ==942:
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elif pointer ==943:
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elif pointer ==944:
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elif pointer ==945:
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elif pointer ==946:
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elif pointer ==947:
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elif pointer ==948:
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elif pointer ==949:
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elif pointer ==950:
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elif pointer ==951:
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 return m_point_951
elif pointer ==952:
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elif pointer ==953:
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elif pointer ==954:
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elif pointer ==964:
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elif pointer ==966:
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elif pointer ==967:
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elif pointer ==968:
 return m_point_968
elif pointer ==969:
 return m_point_969
elif pointer ==970:
 return m_point_970
elif pointer ==971:
 return m_point_971
elif pointer ==972:
 return m_point_972
elif pointer ==973:
 return m_point_973
elif pointer ==974:
 return m_point_974
elif pointer ==975:
 return m_point_975
elif pointer ==976:
 return m_point_976
elif pointer ==977:
 return m_point_977
elif pointer ==978:
 return m_point_978
elif pointer ==979:
 return m_point_979
elif pointer ==980:
 return m_point_980
elif pointer ==981:
 return m_point_981
elif pointer ==982:
 return m_point_982
elif pointer ==983:
 return m_point_983
elif pointer ==984:
 return m_point_984
elif pointer ==985:
 return m_point_985
elif pointer ==986:
```

```
 return m_point_986
 elif pointer ==987:
  return m_point_987
 elif pointer ==988:
  return m_point_988
 elif pointer ==989:
  return m_point_989
 elif pointer ==990:
  return m_point_990
 elif pointer ==991:
  return m_point_991
 elif pointer ==992:
  return m_point_992
 elif pointer ==993:
  return m_point_993
 elif pointer ==994:
  return m_point_994
 elif pointer ==995:
  return m_point_995
 elif pointer ==996:
  return m_point_996
 elif pointer ==997:
  return m_point_997
 elif pointer ==998:
  return m_point_998
 elif pointer ==999:
  return m_point_999
		else:
				return p[0,0,0,0,0,0]
		end
end

def set_point(pointer =0, point = 0):
		if pointer == 0:
				m_point_0 = point
 elif pointer ==1:
  m_point_1= point
 elif pointer ==2:
  m_point_2= point
 elif pointer ==3:
  m_point_3= point
 elif pointer ==4:
  m_point_4= point
 elif pointer ==5:
  m_point_5= point
 elif pointer ==6:
  m_point_6= point
 elif pointer ==7:
  m_point_7= point
 elif pointer ==8:
  m_point_8= point
 elif pointer ==9:
  m_point_9= point
 elif pointer ==10:
  m_point_10= point
 elif pointer ==11:
  m_point_11= point
 elif pointer ==12:
  m_point_12= point
 elif pointer ==13:
  m_point_13= point
 elif pointer ==14:
  m_point_14= point
 elif pointer ==15:
  m_point_15= point
 elif pointer ==16:
  m_point_16= point
 elif pointer ==17:
  m_point_17= point
 elif pointer ==18:
```

```
 m_point_18= point
elif pointer ==19:
 m_point_19= point
elif pointer ==20:
 m_point_20= point
elif pointer ==21:
 m_point_21= point
elif pointer ==22:
 m_point_22= point
elif pointer ==23:
 m_point_23= point
elif pointer ==24:
 m_point_24= point
elif pointer ==25:
 m_point_25= point
elif pointer ==26:
 m_point_26= point
elif pointer ==27:
 m_point_27= point
elif pointer ==28:
 m_point_28= point
elif pointer ==29:
 m_point_29= point
elif pointer ==30:
 m_point_30= point
elif pointer ==31:
 m_point_31= point
elif pointer ==32:
 m_point_32= point
elif pointer ==33:
 m_point_33= point
elif pointer ==34:
 m_point_34= point
elif pointer ==35:
 m_point_35= point
elif pointer ==36:
 m_point_36= point
elif pointer ==37:
 m_point_37= point
elif pointer ==38:
 m_point_38= point
elif pointer ==39:
 m_point_39= point
elif pointer ==40:
 m_point_40= point
elif pointer ==41:
 m_point_41= point
elif pointer ==42:
 m_point_42= point
elif pointer ==43:
 m_point_43= point
elif pointer ==44:
 m_point_44= point
elif pointer ==45:
 m_point_45= point
elif pointer ==46:
 m_point_46= point
elif pointer ==47:
 m_point_47= point
elif pointer ==48:
 m_point_48= point
elif pointer ==49:
 m_point_49= point
elif pointer ==50:
 m_point_50= point
elif pointer ==51:
 m_point_51= point
elif pointer ==52:
 m_point_52= point
elif pointer ==53:
```

```
 m_point_53= point
elif pointer ==54:
 m_point_54= point
elif pointer ==55:
 m_point_55= point
elif pointer ==56:
 m_point_56= point
elif pointer ==57:
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elif pointer ==58:
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elif pointer ==60:
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elif pointer ==63:
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elif pointer ==64:
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elif pointer ==65:
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elif pointer ==66:
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elif pointer ==67:
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elif pointer ==68:
 m_point_68= point
elif pointer ==69:
 m_point_69= point
elif pointer ==70:
 m_point_70= point
elif pointer ==71:
 m_point_71= point
elif pointer ==72:
 m_point_72= point
elif pointer ==73:
 m_point_73= point
elif pointer ==74:
 m_point_74= point
elif pointer ==75:
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elif pointer ==76:
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elif pointer ==77:
 m_point_77= point
elif pointer ==78:
 m_point_78= point
elif pointer ==79:
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elif pointer ==80:
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elif pointer ==81:
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elif pointer ==82:
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elif pointer ==83:
 m_point_83= point
elif pointer ==84:
 m_point_84= point
elif pointer ==85:
 m_point_85= point
elif pointer ==86:
 m_point_86= point
elif pointer ==87:
 m_point_87= point
elif pointer ==88:
```

```
 m_point_88= point
elif pointer ==89:
 m_point_89= point
elif pointer ==90:
 m_point_90= point
elif pointer ==91:
 m_point_91= point
elif pointer ==92:
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elif pointer ==93:
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elif pointer ==115:
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elif pointer ==116:
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elif pointer ==118:
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elif pointer ==119:
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elif pointer ==120:
 m_point_120= point
elif pointer ==121:
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elif pointer ==122:
 m_point_122= point
elif pointer ==123:
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 m_point_123= point
elif pointer ==124:
 m_point_124= point
elif pointer ==125:
 m_point_125= point
elif pointer ==126:
 m_point_126= point
elif pointer ==127:
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elif pointer ==128:
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 m_point_158= point
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elif pointer ==193:
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 m_point_193= point
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elif pointer ==226:
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elif pointer ==228:
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 m_point_228= point
elif pointer ==229:
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elif pointer ==261:
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elif pointer ==262:
 m_point_262= point
elif pointer ==263:
```

```
 m_point_263= point
elif pointer ==264:
 m_point_264= point
elif pointer ==265:
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elif pointer ==266:
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elif pointer ==296:
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elif pointer ==297:
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elif pointer ==298:
```

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 m_point_298= point
elif pointer ==299:
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elif pointer ==300:
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elif pointer ==302:
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elif pointer ==330:
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elif pointer ==331:
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elif pointer ==332:
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elif pointer ==333:
```

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 m_point_333= point
elif pointer ==334:
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elif pointer ==335:
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elif pointer ==337:
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 m_point_368= point
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 m_point_403= point
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elif pointer ==420:
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elif pointer ==421:
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elif pointer ==469:
 m_point_469= point
elif pointer ==470:
 m_point_470= point
elif pointer ==471:
 m_point_471= point
elif pointer ==472:
 m_point_472= point
elif pointer ==473:
```

```
 m_point_473= point
elif pointer ==474:
 m_point_474= point
elif pointer ==475:
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elif pointer ==476:
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elif pointer ==477:
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elif pointer ==478:
 m_point_478= point
elif pointer ==479:
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elif pointer ==480:
 m_point_480= point
elif pointer ==481:
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elif pointer ==482:
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elif pointer ==483:
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elif pointer ==484:
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elif pointer ==485:
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elif pointer ==486:
 m_point_486= point
elif pointer ==487:
 m_point_487= point
elif pointer ==488:
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elif pointer ==489:
 m_point_489= point
elif pointer ==490:
 m_point_490= point
elif pointer ==491:
 m_point_491= point
elif pointer ==492:
 m_point_492= point
elif pointer ==493:
 m_point_493= point
elif pointer ==494:
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elif pointer ==495:
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elif pointer ==496:
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elif pointer ==497:
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elif pointer ==498:
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elif pointer ==499:
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elif pointer ==500:
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elif pointer ==501:
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elif pointer ==502:
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elif pointer ==503:
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elif pointer ==504:
 m_point_504= point
elif pointer ==505:
 m_point_505= point
elif pointer ==506:
 m_point_506= point
elif pointer ==507:
 m_point_507= point
elif pointer ==508:
```

```
 m_point_508= point
elif pointer ==509:
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elif pointer ==510:
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elif pointer ==511:
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elif pointer ==512:
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elif pointer ==513:
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elif pointer ==514:
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elif pointer ==515:
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elif pointer ==516:
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elif pointer ==517:
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elif pointer ==518:
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elif pointer ==519:
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elif pointer ==520:
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elif pointer ==521:
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elif pointer ==522:
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elif pointer ==523:
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elif pointer ==524:
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elif pointer ==525:
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elif pointer ==526:
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elif pointer ==527:
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elif pointer ==528:
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elif pointer ==529:
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elif pointer ==530:
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elif pointer ==532:
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elif pointer ==534:
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elif pointer ==535:
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elif pointer ==536:
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elif pointer ==537:
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elif pointer ==538:
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elif pointer ==539:
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elif pointer ==540:
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elif pointer ==541:
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elif pointer ==542:
 m_point_542= point
elif pointer ==543:
```

```
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elif pointer ==544:
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elif pointer ==545:
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elif pointer ==546:
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elif pointer ==547:
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elif pointer ==548:
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elif pointer ==549:
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elif pointer ==550:
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elif pointer ==551:
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elif pointer ==552:
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elif pointer ==553:
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elif pointer ==554:
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elif pointer ==555:
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elif pointer ==556:
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elif pointer ==557:
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elif pointer ==558:
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elif pointer ==559:
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elif pointer ==560:
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elif pointer ==561:
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elif pointer ==562:
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elif pointer ==564:
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elif pointer ==567:
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elif pointer ==568:
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elif pointer ==569:
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elif pointer ==570:
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elif pointer ==571:
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elif pointer ==572:
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elif pointer ==573:
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elif pointer ==574:
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elif pointer ==575:
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elif pointer ==576:
 m_point_576= point
elif pointer ==577:
 m_point_577= point
elif pointer ==578:
```

```
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elif pointer ==580:
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elif pointer ==581:
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elif pointer ==582:
 m_point_582= point
elif pointer ==583:
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elif pointer ==584:
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elif pointer ==585:
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elif pointer ==586:
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elif pointer ==587:
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elif pointer ==588:
 m_point_588= point
elif pointer ==589:
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elif pointer ==590:
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elif pointer ==591:
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elif pointer ==592:
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elif pointer ==593:
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elif pointer ==594:
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elif pointer ==595:
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elif pointer ==596:
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elif pointer ==597:
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elif pointer ==598:
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elif pointer ==599:
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elif pointer ==600:
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elif pointer ==601:
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elif pointer ==602:
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elif pointer ==603:
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elif pointer ==604:
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elif pointer ==605:
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elif pointer ==606:
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elif pointer ==607:
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elif pointer ==608:
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elif pointer ==609:
 m_point_609= point
elif pointer ==610:
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elif pointer ==611:
 m_point_611= point
elif pointer ==612:
 m_point_612= point
elif pointer ==613:
```

```
 m_point_613= point
elif pointer ==614:
 m_point_614= point
elif pointer ==615:
 m_point_615= point
elif pointer ==616:
 m_point_616= point
elif pointer ==617:
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elif pointer ==618:
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elif pointer ==619:
 m_point_619= point
elif pointer ==620:
 m_point_620= point
elif pointer ==621:
 m_point_621= point
elif pointer ==622:
 m_point_622= point
elif pointer ==623:
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elif pointer ==624:
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elif pointer ==625:
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elif pointer ==627:
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elif pointer ==628:
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elif pointer ==629:
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elif pointer ==630:
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elif pointer ==631:
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elif pointer ==632:
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elif pointer ==633:
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elif pointer ==634:
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elif pointer ==635:
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elif pointer ==636:
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elif pointer ==637:
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elif pointer ==638:
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elif pointer ==640:
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elif pointer ==644:
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elif pointer ==645:
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elif pointer ==646:
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elif pointer ==647:
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elif pointer ==648:
```

```
 m_point_648= point
elif pointer ==649:
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elif pointer ==650:
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elif pointer ==651:
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elif pointer ==652:
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elif pointer ==653:
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elif pointer ==654:
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elif pointer ==655:
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elif pointer ==656:
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elif pointer ==676:
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elif pointer ==677:
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elif pointer ==678:
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elif pointer ==679:
 m_point_679= point
elif pointer ==680:
 m_point_680= point
elif pointer ==681:
 m_point_681= point
elif pointer ==682:
 m_point_682= point
elif pointer ==683:
```

```
 m_point_683= point
elif pointer ==684:
 m_point_684= point
elif pointer ==685:
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elif pointer ==686:
 m_point_686= point
elif pointer ==687:
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elif pointer ==688:
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elif pointer ==689:
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elif pointer ==690:
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elif pointer ==691:
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elif pointer ==692:
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elif pointer ==694:
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elif pointer ==697:
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elif pointer ==698:
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elif pointer ==699:
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elif pointer ==700:
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elif pointer ==701:
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elif pointer ==702:
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elif pointer ==703:
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elif pointer ==704:
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elif pointer ==705:
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elif pointer ==706:
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elif pointer ==707:
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elif pointer ==708:
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elif pointer ==709:
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elif pointer ==710:
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elif pointer ==711:
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elif pointer ==712:
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elif pointer ==713:
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elif pointer ==714:
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elif pointer ==715:
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elif pointer ==716:
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elif pointer ==717:
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elif pointer ==718:
```

```
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elif pointer ==720:
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elif pointer ==721:
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elif pointer ==722:
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elif pointer ==723:
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elif pointer ==724:
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elif pointer ==725:
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elif pointer ==726:
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elif pointer ==727:
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elif pointer ==728:
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elif pointer ==729:
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elif pointer ==730:
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elif pointer ==731:
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elif pointer ==732:
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elif pointer ==733:
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elif pointer ==734:
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elif pointer ==735:
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elif pointer ==736:
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elif pointer ==737:
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elif pointer ==738:
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elif pointer ==739:
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elif pointer ==740:
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elif pointer ==741:
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elif pointer ==742:
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elif pointer ==743:
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elif pointer ==744:
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elif pointer ==745:
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elif pointer ==746:
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elif pointer ==747:
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elif pointer ==748:
 m_point_748= point
elif pointer ==749:
 m_point_749= point
elif pointer ==750:
 m_point_750= point
elif pointer ==751:
 m_point_751= point
elif pointer ==752:
 m_point_752= point
elif pointer ==753:
```

```
 m_point_753= point
elif pointer ==754:
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elif pointer ==755:
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elif pointer ==756:
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elif pointer ==757:
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elif pointer ==758:
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elif pointer ==759:
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elif pointer ==760:
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elif pointer ==761:
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elif pointer ==762:
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elif pointer ==763:
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elif pointer ==764:
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elif pointer ==765:
 m_point_765= point
elif pointer ==766:
 m_point_766= point
elif pointer ==767:
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elif pointer ==768:
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elif pointer ==769:
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elif pointer ==770:
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elif pointer ==771:
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elif pointer ==772:
 m_point_772= point
elif pointer ==773:
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elif pointer ==774:
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elif pointer ==775:
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elif pointer ==776:
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elif pointer ==777:
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elif pointer ==778:
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elif pointer ==779:
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elif pointer ==780:
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elif pointer ==781:
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elif pointer ==782:
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elif pointer ==783:
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elif pointer ==784:
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elif pointer ==785:
 m_point_785= point
elif pointer ==786:
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elif pointer ==787:
 m_point_787= point
elif pointer ==788:
```

```
 m_point_788= point
elif pointer ==789:
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elif pointer ==790:
 m_point_790= point
elif pointer ==791:
 m_point_791= point
elif pointer ==792:
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elif pointer ==793:
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elif pointer ==794:
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elif pointer ==795:
 m_point_795= point
elif pointer ==796:
 m_point_796= point
elif pointer ==797:
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elif pointer ==798:
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elif pointer ==799:
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elif pointer ==800:
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elif pointer ==801:
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elif pointer ==802:
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elif pointer ==803:
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elif pointer ==804:
 m_point_804= point
elif pointer ==805:
 m_point_805= point
elif pointer ==806:
 m_point_806= point
elif pointer ==807:
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elif pointer ==808:
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elif pointer ==809:
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elif pointer ==810:
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elif pointer ==811:
 m_point_811= point
elif pointer ==812:
 m_point_812= point
elif pointer ==813:
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elif pointer ==814:
 m_point_814= point
elif pointer ==815:
 m_point_815= point
elif pointer ==816:
 m_point_816= point
elif pointer ==817:
 m_point_817= point
elif pointer ==818:
 m_point_818= point
elif pointer ==819:
 m_point_819= point
elif pointer ==820:
 m_point_820= point
elif pointer ==821:
 m_point_821= point
elif pointer ==822:
 m_point_822= point
elif pointer ==823:
```

```
 m_point_823= point
elif pointer ==824:
 m_point_824= point
elif pointer ==825:
 m_point_825= point
elif pointer ==826:
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elif pointer ==827:
 m_point_827= point
elif pointer ==828:
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elif pointer ==829:
 m_point_829= point
elif pointer ==830:
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elif pointer ==831:
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elif pointer ==832:
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elif pointer ==833:
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elif pointer ==834:
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elif pointer ==835:
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elif pointer ==836:
 m_point_836= point
elif pointer ==837:
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elif pointer ==838:
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elif pointer ==839:
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elif pointer ==840:
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elif pointer ==841:
 m_point_841= point
elif pointer ==842:
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elif pointer ==843:
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elif pointer ==844:
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elif pointer ==845:
 m_point_845= point
elif pointer ==846:
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elif pointer ==847:
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elif pointer ==848:
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elif pointer ==849:
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elif pointer ==850:
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elif pointer ==851:
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elif pointer ==852:
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elif pointer ==853:
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elif pointer ==854:
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elif pointer ==855:
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elif pointer ==856:
 m_point_856= point
elif pointer ==857:
 m_point_857= point
elif pointer ==858:
```

```
 m_point_858= point
elif pointer ==859:
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elif pointer ==860:
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elif pointer ==861:
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elif pointer ==863:
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elif pointer ==872:
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elif pointer ==873:
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elif pointer ==874:
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elif pointer ==875:
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elif pointer ==876:
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elif pointer ==877:
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elif pointer ==878:
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elif pointer ==879:
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elif pointer ==880:
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elif pointer ==881:
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elif pointer ==882:
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elif pointer ==883:
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elif pointer ==884:
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elif pointer ==886:
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elif pointer ==887:
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elif pointer ==888:
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elif pointer ==889:
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elif pointer ==890:
 m_point_890= point
elif pointer ==891:
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elif pointer ==892:
 m_point_892= point
elif pointer ==893:
```

```
 m_point_893= point
elif pointer ==894:
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elif pointer ==896:
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elif pointer ==897:
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elif pointer ==898:
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elif pointer ==900:
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elif pointer ==901:
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elif pointer ==902:
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elif pointer ==903:
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elif pointer ==904:
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elif pointer ==905:
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elif pointer ==906:
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elif pointer ==907:
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elif pointer ==908:
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elif pointer ==909:
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elif pointer ==911:
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elif pointer ==914:
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elif pointer ==915:
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elif pointer ==916:
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elif pointer ==917:
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elif pointer ==918:
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elif pointer ==919:
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elif pointer ==920:
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elif pointer ==921:
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elif pointer ==922:
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elif pointer ==923:
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elif pointer ==924:
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elif pointer ==925:
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elif pointer ==926:
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elif pointer ==927:
 m_point_927= point
elif pointer ==928:
```

```
 m_point_928= point
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elif pointer ==959:
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elif pointer ==960:
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 m_point_961= point
elif pointer ==962:
 m_point_962= point
elif pointer ==963:
```

```
 m_point_963= point
elif pointer ==964:
 m_point_964= point
elif pointer ==965:
 m_point_965= point
elif pointer ==966:
 m_point_966= point
elif pointer ==967:
 m_point_967= point
elif pointer ==968:
 m_point_968= point
elif pointer ==969:
 m_point_969= point
elif pointer ==970:
 m_point_970= point
elif pointer ==971:
 m_point_971= point
elif pointer ==972:
 m_point_972= point
elif pointer ==973:
 m_point_973= point
elif pointer ==974:
 m_point_974= point
elif pointer ==975:
 m_point_975= point
elif pointer ==976:
 m_point_976= point
elif pointer ==977:
 m_point_977= point
elif pointer ==978:
 m_point_978= point
elif pointer ==979:
 m_point_979= point
elif pointer ==980:
 m_point_980= point
elif pointer ==981:
 m_point_981= point
elif pointer ==982:
 m_point_982= point
elif pointer ==983:
 m_point_983= point
elif pointer ==984:
 m_point_984= point
elif pointer ==985:
 m_point_985= point
elif pointer ==986:
 m_point_986= point
elif pointer ==987:
 m_point_987= point
elif pointer ==988:
 m_point_988= point
elif pointer ==989:
 m_point_989= point
elif pointer ==990:
 m_point_990= point
elif pointer ==991:
 m_point_991= point
elif pointer ==992:
 m_point_992= point
elif pointer ==993:
 m_point_993= point
elif pointer ==994:
 m_point_994= point
elif pointer ==995:
 m_point_995= point
elif pointer ==996:
 m_point_996= point
elif pointer ==997:
 m_point_997= point
elif pointer ==998:
```

```
  m_point_998= point
 elif pointer ==999:
  m_point_999= point
              else:

              end
end
while (True):
  $ 8 "Robot Program"
  $ 9 "Loop socket ≟ False"
  while (socket  ==  False):
    $ 10 "socket≔socket_open('192.168.80.10', 888)"
    global socket=socket_open("192.168.80.10", 888)
    $ 11 "Wait: 1.0"
    sleep(1.0)
  end
  $ 12 "data≔socket_read_ascii_float(8)"
  global data=socket_read_ascii_float(8)
  $ 13 "If data[0] ≠ 0"
  if (data[0]  !=  0):
    $ 14 "Switch data[1]"
    switch_1 = data[1]
    if (0 == switch_1):
      $ 16 "movep(p[data[2],data[3],data[4],data[5],data[6],data[7]], a=0.2, v=data[8], r=0)"
      movep(p[data[2],data[3],data[4],data[5],data[6],data[7]], a=0.2, v=data[8], r=0)
    elif (1 == switch_1):
      $ 18 "If data[2] ≟ 0"
      if (data[2]  ==  0):
        $ 19 "set_standard_digital_out(0,  False )"
        set_standard_digital_out(0,   False  )
      else:
        $ 20 "Else"
        $ 21 "set_standard_digital_out(0,  True )"
        set_standard_digital_out(0,   True  )
      end
    elif (2 == switch_1):
      $ 23 "set_standard_analog_out(0, data[2])"
      set_standard_analog_out(0, data[2])
    elif (3 == switch_1):
      $ 25 "stopl(0.2)"
      stopl(0.2)
    elif (4 == switch_1):
      $ 27 "movel(p[data[2],data[3],data[4],data[5],data[6],data[7]], a=0.2, v=data[8], t=0, r=0)"
      movel(p[data[2],data[3],data[4],data[5],data[6],data[7]], a=0.2, v=data[8], t=0, r=0)
    elif (5 == switch_1):
      $ 29 "set_point(counter, p[data[2], data[3], data[4], data[5], data[6], data[7]])"
      set_point(counter, p[data[2], data[3], data[4], data[5], data[6], data[7]])
      $ 30 "counter = counter + 1"
      counter = counter + 1
    elif (6 == switch_1):
      $ 32 "Loop loop_counter<counter"
      while (loop_counter<counter):
        $ 33 "point≔get_point(loop_counter)"
        global point=get_point(loop_counter)
        $ 34 "loop_counter≔loop_counter + 1"
        global loop_counter=loop_counter + 1
        $ 35 "movep(point, a=0.2, v=speed, r=0.001)"
        movep(point, a=0.2, v=speed, r=0.001)
      end
      $ 36 "stopl(0.5)"
      stopl(0.5)
      $ 37 "counter=0"
      counter=0
      $ 38 "loop_counter=0"
      loop_counter=0
    elif (7 == switch_1):
      $ 40 "speed≔data[2]"
      global speed=data[2]
    elif (8 == switch_1):
      $ 42 "Loop loop_counter<counter"
```

```
        while (loop_counter<counter):
          $ 43 "point:=get_point(loop_counter)"
          global point=get_point(loop_counter)
          $ 44 "loop_counter:=loop_counter + 1"
          global loop_counter=loop_counter + 1
          $ 45 "movel(point, a=0.2, v=speed, r=0.001)"
          movel(point, a=0.2, v=speed, r=0.001)
        end
        $ 46 "stopl(1)"
        stopl(1)
        $ 47 "counter=0"
        counter=0
        $ 48 "loop_counter=0"
        loop_counter=0
      end
      $ 49 "socket_send_string('command_finished')"
      socket_send_string("command_finished")
    end
    $ 50 "Wait: 0.001"
    sleep(0.001)
  end
end
```

4. pielikums

Eksperimentu stenda lietotāja saskarnes galvenā loga elementu izkārtojuma kods

```
namespace UR10
{
    partial class FormMain
    {
        /// <summary>
        /// Required designer variable.
        /// </summary>
        private System.ComponentModel.IContainer components = null;

        /// <summary>
        /// Clean up any resources being used.
        /// </summary>
        /// <param name="disposing">true if managed resources should be disposed; otherwise, false.</param>
        protected override void Dispose(bool disposing)
        {
            if (disposing && (components != null))
            {
                components.Dispose();
            }
            base.Dispose(disposing);
        }

        #region Windows Form Designer generated code

        /// <summary>
        /// Required method for Designer support - do not modify
        /// the contents of this method with the code editor.
        /// </summary>
        private void InitializeComponent()
        {
            System.ComponentModel.ComponentResourceManager resources = new
System.ComponentModel.ComponentResourceManager(typeof(FormMain));
            this.tabControl = new System.Windows.Forms.TabControl();
            this.tabPageUser = new System.Windows.Forms.TabPage();
            this.groupBoxColumnControl = new System.Windows.Forms.GroupBox();
            this.numericUpDownWeedInterval = new System.Windows.Forms.NumericUpDown();
            this.labelWeedInterval = new System.Windows.Forms.Label();
            this.numericUpDownWeedColumns = new System.Windows.Forms.NumericUpDown();
            this.labelWeedColumns = new System.Windows.Forms.Label();
            this.buttonStop = new System.Windows.Forms.Button();
            this.buttonHomeMode = new System.Windows.Forms.Button();
            this.buttonTransportationMode = new System.Windows.Forms.Button();
            this.buttonRunPattern = new System.Windows.Forms.Button();
            this.labelUrPlatformMap = new System.Windows.Forms.Label();
            this.pictureBoxUrPlatform = new System.Windows.Forms.PictureBox();
            this.groupBoxCoordinates = new System.Windows.Forms.GroupBox();
            this.labelZ = new System.Windows.Forms.Label();
            this.labelY = new System.Windows.Forms.Label();
            this.labelX = new System.Windows.Forms.Label();
            this.groupBoxCommunication = new System.Windows.Forms.GroupBox();
            this.buttonConnect = new System.Windows.Forms.Button();
            this.buttonDisconnect = new System.Windows.Forms.Button();
            this.groupBoxRowControl = new System.Windows.Forms.GroupBox();
            this.numericUpDownRow4Distance = new System.Windows.Forms.NumericUpDown();
            this.numericUpDownRow3Distance = new System.Windows.Forms.NumericUpDown();
            this.numericUpDownRow2Distance = new System.Windows.Forms.NumericUpDown();
            this.numericUpDownRow1Distance = new System.Windows.Forms.NumericUpDown();
            this.labelDistances = new System.Windows.Forms.Label();
            this.checkBoxEnableRow1 = new System.Windows.Forms.CheckBox();
            this.checkBoxEnableRow4 = new System.Windows.Forms.CheckBox();
```

```
this.checkBoxEnableRow2 = new System.Windows.Forms.CheckBox();
this.checkBoxEnableRow3 = new System.Windows.Forms.CheckBox();
this.listBoxConsole = new System.Windows.Forms.ListBox();
this.tabPageAdmin = new System.Windows.Forms.TabPage();
this.labelPatternType = new System.Windows.Forms.Label();
this.comboBoxPatternType = new System.Windows.Forms.ComboBox();
this.checkBoxTakePhotos = new System.Windows.Forms.CheckBox();
this.buttonReset = new System.Windows.Forms.Button();
this.labelScale = new System.Windows.Forms.Label();
this.textBoxIpAddress = new System.Windows.Forms.TextBox();
this.labelIpAddress = new System.Windows.Forms.Label();
this.numericUpDownTravelSpeed = new System.Windows.Forms.NumericUpDown();
this.labelTravelSpeed = new System.Windows.Forms.Label();
this.numericUpDownBaseYCoordinate = new System.Windows.Forms.NumericUpDown();
this.labelBaseY = new System.Windows.Forms.Label();
this.numericUpDownBaseXCoordinate = new System.Windows.Forms.NumericUpDown();
this.labelBaseX = new System.Windows.Forms.Label();
this.numericUpDownPatternStartAngle = new System.Windows.Forms.NumericUpDown();
this.numericUpDownDeltaTheta = new System.Windows.Forms.NumericUpDown();
this.labelPatternDeltaTheta = new System.Windows.Forms.Label();
this.pictureBoxPatternSample = new System.Windows.Forms.PictureBox();
this.numericUpDownPatternSpeed = new System.Windows.Forms.NumericUpDown();
this.labelPatterSpeed = new System.Windows.Forms.Label();
this.labelPatternStartAngle = new System.Windows.Forms.Label();
this.numericUpDownPatternStep = new System.Windows.Forms.NumericUpDown();
this.numericUpDownPatterDiameter = new System.Windows.Forms.NumericUpDown();
this.labelPatternStep = new System.Windows.Forms.Label();
this.labelPatternDiameter = new System.Windows.Forms.Label();
this.folderBrowserDialog = new System.Windows.Forms.FolderBrowserDialog();
this.buttonSetPhotosFolderPath = new System.Windows.Forms.Button();
this.groupBoxPhotos = new System.Windows.Forms.GroupBox();
this.tabControl.SuspendLayout();
this.tabPageUser.SuspendLayout();
this.groupBoxColumnControl.SuspendLayout();
((System.ComponentModel.ISupportInitialize)(this.numericUpDownWeedInterval)).BeginInit();
((System.ComponentModel.ISupportInitialize)(this.numericUpDownWeedColumns)).BeginInit();
((System.ComponentModel.ISupportInitialize)(this.pictureBoxUrPlatform)).BeginInit();
this.groupBoxCoordinates.SuspendLayout();
this.groupBoxCommunication.SuspendLayout();
this.groupBoxRowControl.SuspendLayout();
((System.ComponentModel.ISupportInitialize)(this.numericUpDownRow4Distance)).BeginInit();
((System.ComponentModel.ISupportInitialize)(this.numericUpDownRow3Distance)).BeginInit();
((System.ComponentModel.ISupportInitialize)(this.numericUpDownRow2Distance)).BeginInit();
((System.ComponentModel.ISupportInitialize)(this.numericUpDownRow1Distance)).BeginInit();
this.tabPageAdmin.SuspendLayout();
((System.ComponentModel.ISupportInitialize)(this.numericUpDownTravelSpeed)).BeginInit();
((System.ComponentModel.ISupportInitialize)(this.numericUpDownBaseYCoordinate)).BeginInit();
((System.ComponentModel.ISupportInitialize)(this.numericUpDownBaseXCoordinate)).BeginInit();
((System.ComponentModel.ISupportInitialize)(this.numericUpDownPatternStartAngle)).BeginInit();
((System.ComponentModel.ISupportInitialize)(this.numericUpDownDeltaTheta)).BeginInit();
((System.ComponentModel.ISupportInitialize)(this.pictureBoxPatternSample)).BeginInit();
((System.ComponentModel.ISupportInitialize)(this.numericUpDownPatternSpeed)).BeginInit();
((System.ComponentModel.ISupportInitialize)(this.numericUpDownPatternStep)).BeginInit();
((System.ComponentModel.ISupportInitialize)(this.numericUpDownPatterDiameter)).BeginInit();
this.groupBoxPhotos.SuspendLayout();
this.SuspendLayout();
//
// tabControl
//
this.tabControl.Controls.Add(this.tabPageUser);
this.tabControl.Controls.Add(this.tabPageAdmin);
this.tabControl.Dock = System.Windows.Forms.DockStyle.Fill;
this.tabControl.Location = new System.Drawing.Point(0, 0);
this.tabControl.Name = "tabControl";
this.tabControl.SelectedIndex = 0;
this.tabControl.Size = new System.Drawing.Size(824, 539);
this.tabControl.TabIndex = 0;
this.tabControl.Selecting += new System.Windows.Forms.TabControlCancelEventHandler(this.tabControl_Selecting);
//
// tabPageUser
```

```
//
this.tabPageUser.Controls.Add(this.groupBoxColumnControl);
this.tabPageUser.Controls.Add(this.buttonStop);
this.tabPageUser.Controls.Add(this.buttonHomeMode);
this.tabPageUser.Controls.Add(this.buttonTransportationMode);
this.tabPageUser.Controls.Add(this.buttonRunPattern);
this.tabPageUser.Controls.Add(this.labelUrPlatformMap);
this.tabPageUser.Controls.Add(this.pictureBoxUrPlatform);
this.tabPageUser.Controls.Add(this.groupBoxCoordinates);
this.tabPageUser.Controls.Add(this.groupBoxCommunication);
this.tabPageUser.Controls.Add(this.groupBoxRowControl);
this.tabPageUser.Controls.Add(this.listBoxConsole);
this.tabPageUser.Location = new System.Drawing.Point(4, 22);
this.tabPageUser.Name = "tabPageUser";
this.tabPageUser.Padding = new System.Windows.Forms.Padding(3);
this.tabPageUser.Size = new System.Drawing.Size(816, 513);
this.tabPageUser.TabIndex = 0;
this.tabPageUser.Text = "User";
this.tabPageUser.UseVisualStyleBackColor = true;
//
// groupBoxColumnControl
//
this.groupBoxColumnControl.Controls.Add(this.numericUpDownWeedInterval);
this.groupBoxColumnControl.Controls.Add(this.labelWeedInterval);
this.groupBoxColumnControl.Controls.Add(this.numericUpDownWeedColumns);
this.groupBoxColumnControl.Controls.Add(this.labelWeedColumns);
this.groupBoxColumnControl.Location = new System.Drawing.Point(625, 154);
this.groupBoxColumnControl.Name = "groupBoxColumnControl";
this.groupBoxColumnControl.Size = new System.Drawing.Size(181, 87);
this.groupBoxColumnControl.TabIndex = 17;
this.groupBoxColumnControl.TabStop = false;
this.groupBoxColumnControl.Text = "Column control";
//
// numericUpDownWeedInterval
//
this.numericUpDownWeedInterval.Location = new System.Drawing.Point(100, 45);
this.numericUpDownWeedInterval.Maximum = new decimal(new int[] {
500,
0,
0,
0});
this.numericUpDownWeedInterval.Minimum = new decimal(new int[] {
10,
0,
0,
0});
this.numericUpDownWeedInterval.Name = "numericUpDownWeedInterval";
this.numericUpDownWeedInterval.Size = new System.Drawing.Size(71, 20);
this.numericUpDownWeedInterval.TabIndex = 16;
this.numericUpDownWeedInterval.Value = new decimal(new int[] {
10,
0,
0,
0});
this.numericUpDownWeedInterval.Validating += new
System.ComponentModel.CancelEventHandler(this.numericUpDownWeedInterval_Validating);
//
// labelWeedInterval
//
this.labelWeedInterval.AutoSize = true;
this.labelWeedInterval.Location = new System.Drawing.Point(16, 47);
this.labelWeedInterval.Name = "labelWeedInterval";
this.labelWeedInterval.Size = new System.Drawing.Size(67, 13);
this.labelWeedInterval.TabIndex = 15;
this.labelWeedInterval.Text = "Interval (mm)";
//
// numericUpDownWeedColumns
//
this.numericUpDownWeedColumns.Location = new System.Drawing.Point(100, 19);
this.numericUpDownWeedColumns.Maximum = new decimal(new int[] {
```

```
30,
0,
0,
0});
this.numericUpDownWeedColumns.Minimum = new decimal(new int[] {
1,
0,
0,
0});
this.numericUpDownWeedColumns.Name = "numericUpDownWeedColumns";
this.numericUpDownWeedColumns.Size = new System.Drawing.Size(71, 20);
this.numericUpDownWeedColumns.TabIndex = 14;
this.numericUpDownWeedColumns.Value = new decimal(new int[] {
8,
0,
0,
0});
this.numericUpDownWeedColumns.Validating += new System.ComponentModel.CancelEventHandler(this.numericUpDownWeedColumns_Validating);
//
// labelWeedColumns
//
this.labelWeedColumns.AutoSize = true;
this.labelWeedColumns.Location = new System.Drawing.Point(16, 21);
this.labelWeedColumns.Name = "labelWeedColumns";
this.labelWeedColumns.Size = new System.Drawing.Size(78, 13);
this.labelWeedColumns.TabIndex = 13;
this.labelWeedColumns.Text = "Weed columns";
//
// buttonStop
//
this.buttonStop.BackColor = System.Drawing.Color.Red;
this.buttonStop.Enabled = false;
this.buttonStop.Font = new System.Drawing.Font("Microsoft Sans Serif", 8.25F, System.Drawing.FontStyle.Bold, System.Drawing.GraphicsUnit.Point, ((byte)(0)));
this.buttonStop.Location = new System.Drawing.Point(625, 452);
this.buttonStop.Name = "buttonStop";
this.buttonStop.Size = new System.Drawing.Size(181, 53);
this.buttonStop.TabIndex = 16;
this.buttonStop.Text = "STOP";
this.buttonStop.UseVisualStyleBackColor = false;
this.buttonStop.Click += new System.EventHandler(this.ButtonStop_Click);
//
// buttonHomeMode
//
this.buttonHomeMode.Enabled = false;
this.buttonHomeMode.Location = new System.Drawing.Point(625, 393);
this.buttonHomeMode.Name = "buttonHomeMode";
this.buttonHomeMode.Size = new System.Drawing.Size(181, 53);
this.buttonHomeMode.TabIndex = 15;
this.buttonHomeMode.Text = "Home mode";
this.buttonHomeMode.UseVisualStyleBackColor = true;
this.buttonHomeMode.Click += new System.EventHandler(this.ButtonHomeMode_Click);
//
// buttonTransportationMode
//
this.buttonTransportationMode.Enabled = false;
this.buttonTransportationMode.Location = new System.Drawing.Point(625, 334);
this.buttonTransportationMode.Name = "buttonTransportationMode";
this.buttonTransportationMode.Size = new System.Drawing.Size(181, 53);
this.buttonTransportationMode.TabIndex = 14;
this.buttonTransportationMode.Text = "Transportation mode";
this.buttonTransportationMode.UseVisualStyleBackColor = true;
this.buttonTransportationMode.Click += new System.EventHandler(this.ButtonTransportationMode_Click);
//
// buttonRunPattern
//
this.buttonRunPattern.Enabled = false;
this.buttonRunPattern.Location = new System.Drawing.Point(625, 275);
this.buttonRunPattern.Name = "buttonRunPattern";
```

```
this.buttonRunPattern.Size = new System.Drawing.Size(181, 53);
this.buttonRunPattern.TabIndex = 13;
this.buttonRunPattern.Text = "Run pattern";
this.buttonRunPattern.UseVisualStyleBackColor = true;
this.buttonRunPattern.Click += new System.EventHandler(this.ButtonRunPattern_Click);
//
// labelUrPlatformMap
//
this.labelUrPlatformMap.AutoSize = true;
this.labelUrPlatformMap.Location = new System.Drawing.Point(326, 67);
this.labelUrPlatformMap.Name = "labelUrPlatformMap";
this.labelUrPlatformMap.Size = new System.Drawing.Size(88, 13);
this.labelUrPlatformMap.TabIndex = 12;
this.labelUrPlatformMap.Text = "UR Platform Map";
//
// pictureBoxUrPlatform
//
this.pictureBoxUrPlatform.BorderStyle = System.Windows.Forms.BorderStyle.FixedSingle;
this.pictureBoxUrPlatform.Location = new System.Drawing.Point(326, 84);
this.pictureBoxUrPlatform.Name = "pictureBoxUrPlatform";
this.pictureBoxUrPlatform.Size = new System.Drawing.Size(293, 420);
this.pictureBoxUrPlatform.TabIndex = 11;
this.pictureBoxUrPlatform.TabStop = false;
this.pictureBoxUrPlatform.Paint += new System.Windows.Forms.PaintEventHandler(this.PictureBoxUrPlatform_Paint);
//
// groupBoxCoordinates
//
this.groupBoxCoordinates.Controls.Add(this.labelZ);
this.groupBoxCoordinates.Controls.Add(this.labelY);
this.groupBoxCoordinates.Controls.Add(this.labelX);
this.groupBoxCoordinates.Location = new System.Drawing.Point(513, 6);
this.groupBoxCoordinates.Name = "groupBoxCoordinates";
this.groupBoxCoordinates.Size = new System.Drawing.Size(106, 62);
this.groupBoxCoordinates.TabIndex = 10;
this.groupBoxCoordinates.TabStop = false;
this.groupBoxCoordinates.Text = "Head coordinates";
//
// labelZ
//
this.labelZ.AutoSize = true;
this.labelZ.Location = new System.Drawing.Point(6, 42);
this.labelZ.Name = "labelZ";
this.labelZ.Size = new System.Drawing.Size(70, 13);
this.labelZ.TabIndex = 13;
this.labelZ.Text = "Z = unknown";
//
// labelY
//
this.labelY.AutoSize = true;
this.labelY.Location = new System.Drawing.Point(6, 29);
this.labelY.Name = "labelY";
this.labelY.Size = new System.Drawing.Size(70, 13);
this.labelY.TabIndex = 12;
this.labelY.Text = "Y = unknown";
//
// labelX
//
this.labelX.AutoSize = true;
this.labelX.Location = new System.Drawing.Point(6, 16);
this.labelX.Name = "labelX";
this.labelX.Size = new System.Drawing.Size(70, 13);
this.labelX.TabIndex = 11;
this.labelX.Text = "X = unknown";
//
// groupBoxCommunication
//
this.groupBoxCommunication.Controls.Add(this.buttonConnect);
this.groupBoxCommunication.Controls.Add(this.buttonDisconnect);
this.groupBoxCommunication.Location = new System.Drawing.Point(326, 6);
this.groupBoxCommunication.Name = "groupBoxCommunication";
```

```
this.groupBoxCommunication.Size = new System.Drawing.Size(181, 50);
this.groupBoxCommunication.TabIndex = 9;
this.groupBoxCommunication.TabStop = false;
this.groupBoxCommunication.Text = "Communication";
//
// buttonConnect
//
this.buttonConnect.Location = new System.Drawing.Point(6, 19);
this.buttonConnect.Name = "buttonConnect";
this.buttonConnect.Size = new System.Drawing.Size(75, 23);
this.buttonConnect.TabIndex = 0;
this.buttonConnect.Text = "Connect";
this.buttonConnect.UseVisualStyleBackColor = true;
this.buttonConnect.Click += new System.EventHandler(this.buttonConnect_Click);
//
// buttonDisconnect
//
this.buttonDisconnect.Enabled = false;
this.buttonDisconnect.Location = new System.Drawing.Point(87, 19);
this.buttonDisconnect.Name = "buttonDisconnect";
this.buttonDisconnect.Size = new System.Drawing.Size(75, 23);
this.buttonDisconnect.TabIndex = 1;
this.buttonDisconnect.Text = "Disconnect";
this.buttonDisconnect.UseVisualStyleBackColor = true;
this.buttonDisconnect.Click += new System.EventHandler(this.buttonDisconnect_Click);
//
// groupBoxRowControl
//
this.groupBoxRowControl.Controls.Add(this.numericUpDownRow4Distance);
this.groupBoxRowControl.Controls.Add(this.numericUpDownRow3Distance);
this.groupBoxRowControl.Controls.Add(this.numericUpDownRow2Distance);
this.groupBoxRowControl.Controls.Add(this.numericUpDownRow1Distance);
this.groupBoxRowControl.Controls.Add(this.labelDistances);
this.groupBoxRowControl.Controls.Add(this.checkBoxEnableRow1);
this.groupBoxRowControl.Controls.Add(this.checkBoxEnableRow4);
this.groupBoxRowControl.Controls.Add(this.checkBoxEnableRow2);
this.groupBoxRowControl.Controls.Add(this.checkBoxEnableRow3);
this.groupBoxRowControl.Location = new System.Drawing.Point(625, 6);
this.groupBoxRowControl.Name = "groupBoxRowControl";
this.groupBoxRowControl.Size = new System.Drawing.Size(181, 142);
this.groupBoxRowControl.TabIndex = 8;
this.groupBoxRowControl.TabStop = false;
this.groupBoxRowControl.Text = "Row control";
//
// numericUpDownRow4Distance
//
this.numericUpDownRow4Distance.Location = new System.Drawing.Point(100, 112);
this.numericUpDownRow4Distance.Maximum = new decimal(new int[] {
380,
0,
0,
-2147483648});
this.numericUpDownRow4Distance.Minimum = new decimal(new int[] {
480,
0,
0,
-2147483648});
this.numericUpDownRow4Distance.Name = "numericUpDownRow4Distance";
this.numericUpDownRow4Distance.Size = new System.Drawing.Size(71, 20);
this.numericUpDownRow4Distance.TabIndex = 12;
this.numericUpDownRow4Distance.Value = new decimal(new int[] {
430,
0,
0,
-2147483648});
this.numericUpDownRow4Distance.ValueChanged += new
System.EventHandler(this.numericUpDownRow4Distance_ValueChanged);
//
// numericUpDownRow3Distance
//
```

```
this.numericUpDownRow3Distance.Location = new System.Drawing.Point(100, 86);
this.numericUpDownRow3Distance.Maximum = new decimal(new int[] {
480,
0,
0,
-2147483648});
this.numericUpDownRow3Distance.Minimum = new decimal(new int[] {
580,
0,
0,
-2147483648});
this.numericUpDownRow3Distance.Name = "numericUpDownRow3Distance";
this.numericUpDownRow3Distance.Size = new System.Drawing.Size(71, 20);
this.numericUpDownRow3Distance.TabIndex = 11;
this.numericUpDownRow3Distance.Value = new decimal(new int[] {
530,
0,
0,
-2147483648});
this.numericUpDownRow3Distance.ValueChanged += new
System.EventHandler(this.numericUpDownRow3Distance_ValueChanged);
//
// numericUpDownRow2Distance
//
this.numericUpDownRow2Distance.Location = new System.Drawing.Point(100, 60);
this.numericUpDownRow2Distance.Maximum = new decimal(new int[] {
630,
0,
0,
-2147483648});
this.numericUpDownRow2Distance.Minimum = new decimal(new int[] {
730,
0,
0,
-2147483648});
this.numericUpDownRow2Distance.Name = "numericUpDownRow2Distance";
this.numericUpDownRow2Distance.Size = new System.Drawing.Size(71, 20);
this.numericUpDownRow2Distance.TabIndex = 10;
this.numericUpDownRow2Distance.Value = new decimal(new int[] {
680,
0,
0,
-2147483648});
this.numericUpDownRow2Distance.ValueChanged += new
System.EventHandler(this.numericUpDownRow2Distance_ValueChanged);
//
// numericUpDownRow1Distance
//
this.numericUpDownRow1Distance.Location = new System.Drawing.Point(100, 34);
this.numericUpDownRow1Distance.Maximum = new decimal(new int[] {
730,
0,
0,
-2147483648});
this.numericUpDownRow1Distance.Minimum = new decimal(new int[] {
830,
0,
0,
-2147483648});
this.numericUpDownRow1Distance.Name = "numericUpDownRow1Distance";
this.numericUpDownRow1Distance.Size = new System.Drawing.Size(71, 20);
this.numericUpDownRow1Distance.TabIndex = 9;
this.numericUpDownRow1Distance.Value = new decimal(new int[] {
780,
0,
0,
-2147483648});
this.numericUpDownRow1Distance.ValueChanged += new
System.EventHandler(this.numericUpDownRow1Distance_ValueChanged);
//
```

```
// labelDistances
//
this.labelDistances.AutoSize = true;
this.labelDistances.Location = new System.Drawing.Point(97, 16);
this.labelDistances.Name = "labelDistances";
this.labelDistances.Size = new System.Drawing.Size(74, 13);
this.labelDistances.TabIndex = 8;
this.labelDistances.Text = "Distance (mm)";
//
// checkBoxEnableRow1
//
this.checkBoxEnableRow1.AutoSize = true;
this.checkBoxEnableRow1.Location = new System.Drawing.Point(6, 35);
this.checkBoxEnableRow1.Name = "checkBoxEnableRow1";
this.checkBoxEnableRow1.Size = new System.Drawing.Size(88, 17);
this.checkBoxEnableRow1.TabIndex = 4;
this.checkBoxEnableRow1.Text = "Enable row 1";
this.checkBoxEnableRow1.UseVisualStyleBackColor = true;
this.checkBoxEnableRow1.CheckedChanged += new System.EventHandler(this.checkBoxEnableRow1_CheckedChanged);
//
// checkBoxEnableRow4
//
this.checkBoxEnableRow4.AutoSize = true;
this.checkBoxEnableRow4.Location = new System.Drawing.Point(6, 113);
this.checkBoxEnableRow4.Name = "checkBoxEnableRow4";
this.checkBoxEnableRow4.Size = new System.Drawing.Size(88, 17);
this.checkBoxEnableRow4.TabIndex = 7;
this.checkBoxEnableRow4.Text = "Enable row 4";
this.checkBoxEnableRow4.UseVisualStyleBackColor = true;
this.checkBoxEnableRow4.CheckedChanged += new System.EventHandler(this.checkBoxEnableRow4_CheckedChanged);
//
// checkBoxEnableRow2
//
this.checkBoxEnableRow2.AutoSize = true;
this.checkBoxEnableRow2.Location = new System.Drawing.Point(6, 61);
this.checkBoxEnableRow2.Name = "checkBoxEnableRow2";
this.checkBoxEnableRow2.Size = new System.Drawing.Size(88, 17);
this.checkBoxEnableRow2.TabIndex = 5;
this.checkBoxEnableRow2.Text = "Enable row 2";
this.checkBoxEnableRow2.UseVisualStyleBackColor = true;
this.checkBoxEnableRow2.CheckedChanged += new System.EventHandler(this.checkBoxEnableRow2_CheckedChanged);
//
// checkBoxEnableRow3
//
this.checkBoxEnableRow3.AutoSize = true;
this.checkBoxEnableRow3.Location = new System.Drawing.Point(6, 87);
this.checkBoxEnableRow3.Name = "checkBoxEnableRow3";
this.checkBoxEnableRow3.Size = new System.Drawing.Size(88, 17);
this.checkBoxEnableRow3.TabIndex = 6;
this.checkBoxEnableRow3.Text = "Enable row 3";
this.checkBoxEnableRow3.UseVisualStyleBackColor = true;
this.checkBoxEnableRow3.CheckedChanged += new System.EventHandler(this.checkBoxEnableRow3_CheckedChanged);
//
// listBoxConsole
//
this.listBoxConsole.FormattingEnabled = true;
this.listBoxConsole.HorizontalScrollbar = true;
this.listBoxConsole.Location = new System.Drawing.Point(8, 6);
this.listBoxConsole.Name = "listBoxConsole";
this.listBoxConsole.Size = new System.Drawing.Size(312, 498);
this.listBoxConsole.TabIndex = 3;
//
// tabPageAdmin
//
this.tabPageAdmin.Controls.Add(this.groupBoxPhotos);
this.tabPageAdmin.Controls.Add(this.labelPatternType);
this.tabPageAdmin.Controls.Add(this.comboBoxPatternType);
this.tabPageAdmin.Controls.Add(this.buttonReset);
this.tabPageAdmin.Controls.Add(this.labelScale);
this.tabPageAdmin.Controls.Add(this.textBoxIpAddress);
```

```
this.tabPageAdmin.Controls.Add(this.labelIpAddress);
this.tabPageAdmin.Controls.Add(this.numericUpDownTravelSpeed);
this.tabPageAdmin.Controls.Add(this.labelTravelSpeed);
this.tabPageAdmin.Controls.Add(this.numericUpDownBaseYCoordinate);
this.tabPageAdmin.Controls.Add(this.labelBaseY);
this.tabPageAdmin.Controls.Add(this.numericUpDownBaseXCoordinate);
this.tabPageAdmin.Controls.Add(this.labelBaseX);
this.tabPageAdmin.Controls.Add(this.numericUpDownPatternStartAngle);
this.tabPageAdmin.Controls.Add(this.numericUpDownDeltaTheta);
this.tabPageAdmin.Controls.Add(this.labelPatternDeltaTheta);
this.tabPageAdmin.Controls.Add(this.pictureBoxPatternSample);
this.tabPageAdmin.Controls.Add(this.numericUpDownPatternSpeed);
this.tabPageAdmin.Controls.Add(this.labelPatterSpeed);
this.tabPageAdmin.Controls.Add(this.labelPatternStartAngle);
this.tabPageAdmin.Controls.Add(this.numericUpDownPatternStep);
this.tabPageAdmin.Controls.Add(this.numericUpDownPatterDiameter);
this.tabPageAdmin.Controls.Add(this.labelPatternStep);
this.tabPageAdmin.Controls.Add(this.labelPatternDiameter);
this.tabPageAdmin.Location = new System.Drawing.Point(4, 22);
this.tabPageAdmin.Name = "tabPageAdmin";
this.tabPageAdmin.Padding = new System.Windows.Forms.Padding(3);
this.tabPageAdmin.Size = new System.Drawing.Size(816, 513);
this.tabPageAdmin.TabIndex = 1;
this.tabPageAdmin.Text = "Admin";
this.tabPageAdmin.UseVisualStyleBackColor = true;
this.tabPageAdmin.Enter += new System.EventHandler(this.tabPageAdmin_Enter);
//
// labelPatternType
//
this.labelPatternType.AutoSize = true;
this.labelPatternType.Location = new System.Drawing.Point(8, 10);
this.labelPatternType.Name = "labelPatternType";
this.labelPatternType.Size = new System.Drawing.Size(64, 13);
this.labelPatternType.TabIndex = 23;
this.labelPatternType.Text = "Pattern type";
//
// comboBoxPatternType
//
this.comboBoxPatternType.FormattingEnabled = true;
this.comboBoxPatternType.Items.AddRange(new object[] {
"Spiral",
"Zig-Zag"});
this.comboBoxPatternType.Location = new System.Drawing.Point(123, 6);
this.comboBoxPatternType.Name = "comboBoxPatternType";
this.comboBoxPatternType.Size = new System.Drawing.Size(65, 21);
this.comboBoxPatternType.TabIndex = 22;
this.comboBoxPatternType.SelectedIndexChanged += new
System.EventHandler(this.comboBoxPatternType_SelectedIndexChanged);
//
// checkBoxTakePhotos
//
this.checkBoxTakePhotos.AutoSize = true;
this.checkBoxTakePhotos.Location = new System.Drawing.Point(6, 19);
this.checkBoxTakePhotos.Name = "checkBoxTakePhotos";
this.checkBoxTakePhotos.Size = new System.Drawing.Size(86, 17);
this.checkBoxTakePhotos.TabIndex = 21;
this.checkBoxTakePhotos.Text = "Take photos";
this.checkBoxTakePhotos.UseVisualStyleBackColor = true;
this.checkBoxTakePhotos.CheckedChanged += new System.EventHandler(this.checkBoxTakePhotos_CheckedChanged);
//
// buttonReset
//
this.buttonReset.Location = new System.Drawing.Point(228, 130);
this.buttonReset.Name = "buttonReset";
this.buttonReset.Size = new System.Drawing.Size(94, 23);
this.buttonReset.TabIndex = 20;
this.buttonReset.Text = "Reset to default";
this.buttonReset.UseVisualStyleBackColor = true;
this.buttonReset.Click += new System.EventHandler(this.buttonReset_Click);
//
```

```
// labelScale
//
this.labelScale.AutoSize = true;
this.labelScale.Location = new System.Drawing.Point(8, 496);
this.labelScale.Name = "labelScale";
this.labelScale.Size = new System.Drawing.Size(34, 13);
this.labelScale.TabIndex = 19;
this.labelScale.Text = "Scale";
//
// textBoxIpAddress
//
this.textBoxIpAddress.Location = new System.Drawing.Point(303, 61);
this.textBoxIpAddress.Name = "textBoxIpAddress";
this.textBoxIpAddress.Size = new System.Drawing.Size(100, 20);
this.textBoxIpAddress.TabIndex = 18;
this.textBoxIpAddress.Leave += new System.EventHandler(this.TextBoxIpAddress_Leave);
//
// labelIpAddress
//
this.labelIpAddress.AutoSize = true;
this.labelIpAddress.Location = new System.Drawing.Point(228, 64);
this.labelIpAddress.Name = "labelIpAddress";
this.labelIpAddress.Size = new System.Drawing.Size(57, 13);
this.labelIpAddress.TabIndex = 17;
this.labelIpAddress.Text = "IP address";
//
// numericUpDownTravelSpeed
//
this.numericUpDownTravelSpeed.Location = new System.Drawing.Point(338, 89);
this.numericUpDownTravelSpeed.Maximum = new decimal(new int[] {
200,
0,
0,
0});
this.numericUpDownTravelSpeed.Minimum = new decimal(new int[] {
1,
0,
0,
0});
this.numericUpDownTravelSpeed.Name = "numericUpDownTravelSpeed";
this.numericUpDownTravelSpeed.Size = new System.Drawing.Size(65, 20);
this.numericUpDownTravelSpeed.TabIndex = 15;
this.numericUpDownTravelSpeed.Value = new decimal(new int[] {
1,
0,
0,
0});
this.numericUpDownTravelSpeed.ValueChanged += new
System.EventHandler(this.NumericUpDownTravelSpeed_ValueChanged);
//
// labelTravelSpeed
//
this.labelTravelSpeed.AutoSize = true;
this.labelTravelSpeed.Location = new System.Drawing.Point(228, 91);
this.labelTravelSpeed.Name = "labelTravelSpeed";
this.labelTravelSpeed.Size = new System.Drawing.Size(104, 13);
this.labelTravelSpeed.TabIndex = 16;
this.labelTravelSpeed.Text = "Travel speed (mm/s)";
//
// numericUpDownBaseYCoordinate
//
this.numericUpDownBaseYCoordinate.Location = new System.Drawing.Point(338, 33);
this.numericUpDownBaseYCoordinate.Maximum = new decimal(new int[] {
1200,
0,
0,
0});
this.numericUpDownBaseYCoordinate.Name = "numericUpDownBaseYCoordinate";
this.numericUpDownBaseYCoordinate.Size = new System.Drawing.Size(65, 20);
this.numericUpDownBaseYCoordinate.TabIndex = 14;
```

```
this.numericUpDownBaseYCoordinate.Value = new decimal(new int[] {
2,
0,
0,
0});
this.numericUpDownBaseYCoordinate.ValueChanged += new System.EventHandler(this.NumericUpDownBaseYCoordinate_ValueChanged);
//
// labelBaseY
//
this.labelBaseY.AutoSize = true;
this.labelBaseY.Location = new System.Drawing.Point(228, 36);
this.labelBaseY.Name = "labelBaseY";
this.labelBaseY.Size = new System.Drawing.Size(94, 13);
this.labelBaseY.TabIndex = 13;
this.labelBaseY.Text = "Base Y coordinate";
//
// numericUpDownBaseXCoordinate
//
this.numericUpDownBaseXCoordinate.Location = new System.Drawing.Point(338, 7);
this.numericUpDownBaseXCoordinate.Maximum = new decimal(new int[] {
870,
0,
0,
0});
this.numericUpDownBaseXCoordinate.Name = "numericUpDownBaseXCoordinate";
this.numericUpDownBaseXCoordinate.Size = new System.Drawing.Size(65, 20);
this.numericUpDownBaseXCoordinate.TabIndex = 12;
this.numericUpDownBaseXCoordinate.Value = new decimal(new int[] {
2,
0,
0,
0});
this.numericUpDownBaseXCoordinate.ValueChanged += new System.EventHandler(this.NumericUpDownBaseXCoordinate_ValueChanged);
//
// labelBaseX
//
this.labelBaseX.AutoSize = true;
this.labelBaseX.Location = new System.Drawing.Point(228, 10);
this.labelBaseX.Name = "labelBaseX";
this.labelBaseX.Size = new System.Drawing.Size(94, 13);
this.labelBaseX.TabIndex = 11;
this.labelBaseX.Text = "Base X coordinate";
//
// numericUpDownPatternStartAngle
//
this.numericUpDownPatternStartAngle.Location = new System.Drawing.Point(123, 34);
this.numericUpDownPatternStartAngle.Maximum = new decimal(new int[] {
360,
0,
0,
0});
this.numericUpDownPatternStartAngle.Name = "numericUpDownPatternStartAngle";
this.numericUpDownPatternStartAngle.Size = new System.Drawing.Size(65, 20);
this.numericUpDownPatternStartAngle.TabIndex = 10;
this.numericUpDownPatternStartAngle.Value = new decimal(new int[] {
2,
0,
0,
0});
this.numericUpDownPatternStartAngle.ValueChanged += new System.EventHandler(this.numericUpDownPatternStartAngle_ValueChanged);
//
// numericUpDownDeltaTheta
//
this.numericUpDownDeltaTheta.Location = new System.Drawing.Point(123, 60);
this.numericUpDownDeltaTheta.Maximum = new decimal(new int[] {
160,
0,
```

```
0,
0});
this.numericUpDownDeltaTheta.Minimum = new decimal(new int[] {
1,
0,
0,
0});
this.numericUpDownDeltaTheta.Name = "numericUpDownDeltaTheta";
this.numericUpDownDeltaTheta.Size = new System.Drawing.Size(65, 20);
this.numericUpDownDeltaTheta.TabIndex = 8;
this.numericUpDownDeltaTheta.Value = new decimal(new int[] {
1,
0,
0,
0});
this.numericUpDownDeltaTheta.ValueChanged += new
System.EventHandler(this.numericUpDownDeltaTheta_ValueChanged);
//
// labelPatternDeltaTheta
//
this.labelPatternDeltaTheta.AutoSize = true;
this.labelPatternDeltaTheta.Location = new System.Drawing.Point(8, 62);
this.labelPatternDeltaTheta.Name = "labelPatternDeltaTheta";
this.labelPatternDeltaTheta.Size = new System.Drawing.Size(94, 13);
this.labelPatternDeltaTheta.TabIndex = 9;
this.labelPatternDeltaTheta.Text = "Pattern delta theta";
//
// pictureBoxPatternSample
//
this.pictureBoxPatternSample.BorderStyle = System.Windows.Forms.BorderStyle.FixedSingle;
this.pictureBoxPatternSample.Location = new System.Drawing.Point(11, 164);
this.pictureBoxPatternSample.Name = "pictureBoxPatternSample";
this.pictureBoxPatternSample.Size = new System.Drawing.Size(329, 329);
this.pictureBoxPatternSample.TabIndex = 7;
this.pictureBoxPatternSample.TabStop = false;
this.pictureBoxPatternSample.Paint += new System.Windows.Forms.PaintEventHandler(this.pictureBoxPatternSample_Paint);
//
// numericUpDownPatternSpeed
//
this.numericUpDownPatternSpeed.Location = new System.Drawing.Point(123, 138);
this.numericUpDownPatternSpeed.Maximum = new decimal(new int[] {
200,
0,
0,
0});
this.numericUpDownPatternSpeed.Minimum = new decimal(new int[] {
1,
0,
0,
0});
this.numericUpDownPatternSpeed.Name = "numericUpDownPatternSpeed";
this.numericUpDownPatternSpeed.Size = new System.Drawing.Size(65, 20);
this.numericUpDownPatternSpeed.TabIndex = 3;
this.numericUpDownPatternSpeed.Value = new decimal(new int[] {
1,
0,
0,
0});
this.numericUpDownPatternSpeed.ValueChanged += new
System.EventHandler(this.numericUpDownPatternSpeed_ValueChanged);
//
// labelPatterSpeed
//
this.labelPatterSpeed.AutoSize = true;
this.labelPatterSpeed.Location = new System.Drawing.Point(8, 140);
this.labelPatterSpeed.Name = "labelPatterSpeed";
this.labelPatterSpeed.Size = new System.Drawing.Size(108, 13);
this.labelPatterSpeed.TabIndex = 6;
this.labelPatterSpeed.Text = "Pattern speed (mm/s)";
//
```

```
// labelPatternStartAngle
//
this.labelPatternStartAngle.AutoSize = true;
this.labelPatternStartAngle.Location = new System.Drawing.Point(8, 36);
this.labelPatternStartAngle.Name = "labelPatternStartAngle";
this.labelPatternStartAngle.Size = new System.Drawing.Size(93, 13);
this.labelPatternStartAngle.TabIndex = 5;
this.labelPatternStartAngle.Text = "Pattern start angle";
//
// numericUpDownPatternStep
//
this.numericUpDownPatternStep.DecimalPlaces = 1;
this.numericUpDownPatternStep.Increment = new decimal(new int[] {
1,
0,
0,
65536});
this.numericUpDownPatternStep.Location = new System.Drawing.Point(123, 112);
this.numericUpDownPatternStep.Maximum = new decimal(new int[] {
10,
0,
0,
0});
this.numericUpDownPatternStep.Minimum = new decimal(new int[] {
1,
0,
0,
65536});
this.numericUpDownPatternStep.Name = "numericUpDownPatternStep";
this.numericUpDownPatternStep.Size = new System.Drawing.Size(65, 20);
this.numericUpDownPatternStep.TabIndex = 2;
this.numericUpDownPatternStep.Value = new decimal(new int[] {
5,
0,
0,
65536});
this.numericUpDownPatternStep.ValueChanged += new
System.EventHandler(this.numericUpDownPatternStep_ValueChanged);
//
// numericUpDownPatterDiameter
//
this.numericUpDownPatterDiameter.Location = new System.Drawing.Point(123, 86);
this.numericUpDownPatterDiameter.Maximum = new decimal(new int[] {
90,
0,
0,
0});
this.numericUpDownPatterDiameter.Minimum = new decimal(new int[] {
2,
0,
0,
0});
this.numericUpDownPatterDiameter.Name = "numericUpDownPatterDiameter";
this.numericUpDownPatterDiameter.Size = new System.Drawing.Size(65, 20);
this.numericUpDownPatterDiameter.TabIndex = 1;
this.numericUpDownPatterDiameter.Value = new decimal(new int[] {
2,
0,
0,
0});
this.numericUpDownPatterDiameter.ValueChanged += new
System.EventHandler(this.numericUpDownPatterDiameter_ValueChanged);
//
// labelPatternStep
//
this.labelPatternStep.AutoSize = true;
this.labelPatternStep.Location = new System.Drawing.Point(8, 114);
this.labelPatternStep.Name = "labelPatternStep";
this.labelPatternStep.Size = new System.Drawing.Size(64, 13);
this.labelPatternStep.TabIndex = 2;
```

```
this.labelPatternStep.Text = "Pattern step";
//
// labelPatternDiameter
//
this.labelPatternDiameter.AutoSize = true;
this.labelPatternDiameter.Location = new System.Drawing.Point(8, 88);
this.labelPatternDiameter.Name = "labelPatternDiameter";
this.labelPatternDiameter.Size = new System.Drawing.Size(109, 13);
this.labelPatternDiameter.TabIndex = 1;
this.labelPatternDiameter.Text = "Pattern diamater (mm)";
//
// folderBrowserDialog
//
this.folderBrowserDialog.Description = "Select photos folder path";
//
// buttonSetPhotosFolderPath
//
this.buttonSetPhotosFolderPath.Location = new System.Drawing.Point(6, 42);
this.buttonSetPhotosFolderPath.Name = "buttonSetPhotosFolderPath";
this.buttonSetPhotosFolderPath.Size = new System.Drawing.Size(101, 23);
this.buttonSetPhotosFolderPath.TabIndex = 24;
this.buttonSetPhotosFolderPath.Text = "Set folder path...";
this.buttonSetPhotosFolderPath.UseVisualStyleBackColor = true;
this.buttonSetPhotosFolderPath.Click += new System.EventHandler(this.buttonSetPhotosFolderPath_Click);
//
// groupBoxPhotos
//
this.groupBoxPhotos.Controls.Add(this.checkBoxTakePhotos);
this.groupBoxPhotos.Controls.Add(this.buttonSetPhotosFolderPath);
this.groupBoxPhotos.Location = new System.Drawing.Point(439, 6);
this.groupBoxPhotos.Name = "groupBoxPhotos";
this.groupBoxPhotos.Size = new System.Drawing.Size(133, 73);
this.groupBoxPhotos.TabIndex = 25;
this.groupBoxPhotos.TabStop = false;
this.groupBoxPhotos.Text = "Photos settings";
//
// FormMain
//
this.AutoScaleDimensions = new System.Drawing.SizeF(6F, 13F);
this.AutoScaleMode = System.Windows.Forms.AutoScaleMode.Font;
this.ClientSize = new System.Drawing.Size(824, 539);
this.Controls.Add(this.tabControl);
this.Icon = ((System.Drawing.Icon)(resources.GetObject("$this.Icon")));
this.Name = "FormMain";
this.ShowIcon = false;
this.Text = "UR10 Lasering Manager";
this.tabControl.ResumeLayout(false);
this.tabPageUser.ResumeLayout(false);
this.tabPageUser.PerformLayout();
this.groupBoxColumnControl.ResumeLayout(false);
this.groupBoxColumnControl.PerformLayout();
((System.ComponentModel.ISupportInitialize)(this.numericUpDownWeedInterval)).EndInit();
((System.ComponentModel.ISupportInitialize)(this.numericUpDownWeedColumns)).EndInit();
((System.ComponentModel.ISupportInitialize)(this.pictureBoxUrPlatform)).EndInit();
this.groupBoxCoordinates.ResumeLayout(false);
this.groupBoxCoordinates.PerformLayout();
this.groupBoxCommunication.ResumeLayout(false);
this.groupBoxRowControl.ResumeLayout(false);
this.groupBoxRowControl.PerformLayout();
((System.ComponentModel.ISupportInitialize)(this.numericUpDownRow4Distance)).EndInit();
((System.ComponentModel.ISupportInitialize)(this.numericUpDownRow3Distance)).EndInit();
((System.ComponentModel.ISupportInitialize)(this.numericUpDownRow2Distance)).EndInit();
((System.ComponentModel.ISupportInitialize)(this.numericUpDownRow1Distance)).EndInit();
this.tabPageAdmin.ResumeLayout(false);
this.tabPageAdmin.PerformLayout();
((System.ComponentModel.ISupportInitialize)(this.numericUpDownTravelSpeed)).EndInit();
((System.ComponentModel.ISupportInitialize)(this.numericUpDownBaseYCoordinate)).EndInit();
((System.ComponentModel.ISupportInitialize)(this.numericUpDownBaseXCoordinate)).EndInit();
((System.ComponentModel.ISupportInitialize)(this.numericUpDownPatternStartAngle)).EndInit();
((System.ComponentModel.ISupportInitialize)(this.numericUpDownDeltaTheta)).EndInit();
```

```
    ((System.ComponentModel.ISupportInitialize)(this.pictureBoxPatternSample)).EndInit();
    ((System.ComponentModel.ISupportInitialize)(this.numericUpDownPatternSpeed)).EndInit();
    ((System.ComponentModel.ISupportInitialize)(this.numericUpDownPatternStep)).EndInit();
    ((System.ComponentModel.ISupportInitialize)(this.numericUpDownPatterDiameter)).EndInit();
    this.groupBoxPhotos.ResumeLayout(false);
    this.groupBoxPhotos.PerformLayout();
    this.ResumeLayout(false);

}

#endregion

private System.Windows.Forms.TabControl tabControl;
private System.Windows.Forms.TabPage tabPageUser;
private System.Windows.Forms.TabPage tabPageAdmin;
private System.Windows.Forms.Button buttonDisconnect;
private System.Windows.Forms.Button buttonConnect;
private System.Windows.Forms.ListBox listBoxConsole;
private System.Windows.Forms.NumericUpDown numericUpDownPatternStep;
private System.Windows.Forms.NumericUpDown numericUpDownPatterDiameter;
private System.Windows.Forms.Label labelPatternStep;
private System.Windows.Forms.Label labelPatternDiameter;
private System.Windows.Forms.Label labelPatternStartAngle;
private System.Windows.Forms.NumericUpDown numericUpDownPatternSpeed;
private System.Windows.Forms.Label labelPatterSpeed;
private System.Windows.Forms.GroupBox groupBoxRowControl;
private System.Windows.Forms.CheckBox checkBoxEnableRow1;
private System.Windows.Forms.CheckBox checkBoxEnableRow4;
private System.Windows.Forms.CheckBox checkBoxEnableRow2;
private System.Windows.Forms.CheckBox checkBoxEnableRow3;
private System.Windows.Forms.NumericUpDown numericUpDownRow4Distance;
private System.Windows.Forms.NumericUpDown numericUpDownRow3Distance;
private System.Windows.Forms.NumericUpDown numericUpDownRow2Distance;
private System.Windows.Forms.NumericUpDown numericUpDownRow1Distance;
private System.Windows.Forms.Label labelDistances;
private System.Windows.Forms.GroupBox groupBoxCommunication;
private System.Windows.Forms.NumericUpDown numericUpDownDeltaTheta;
private System.Windows.Forms.Label labelPatternDeltaTheta;
private System.Windows.Forms.PictureBox pictureBoxPatternSample;
private System.Windows.Forms.NumericUpDown numericUpDownPatternStartAngle;
private System.Windows.Forms.GroupBox groupBoxCoordinates;
private System.Windows.Forms.Label labelZ;
private System.Windows.Forms.Label labelY;
private System.Windows.Forms.Label labelX;
private System.Windows.Forms.PictureBox pictureBoxUrPlatform;
private System.Windows.Forms.NumericUpDown numericUpDownBaseYCoordinate;
private System.Windows.Forms.Label labelBaseY;
private System.Windows.Forms.NumericUpDown numericUpDownBaseXCoordinate;
private System.Windows.Forms.Label labelBaseX;
private System.Windows.Forms.Label labelUrPlatformMap;
private System.Windows.Forms.Button buttonRunPattern;
private System.Windows.Forms.NumericUpDown numericUpDownTravelSpeed;
private System.Windows.Forms.Label labelTravelSpeed;
private System.Windows.Forms.Button buttonTransportationMode;
private System.Windows.Forms.TextBox textBoxIpAddress;
private System.Windows.Forms.Label labelIpAddress;
private System.Windows.Forms.Button buttonHomeMode;
private System.Windows.Forms.Button buttonStop;
private System.Windows.Forms.Label labelScale;
private System.Windows.Forms.Button buttonReset;
private System.Windows.Forms.NumericUpDown numericUpDownWeedColumns;
private System.Windows.Forms.Label labelWeedColumns;
private System.Windows.Forms.GroupBox groupBoxColumnControl;
private System.Windows.Forms.NumericUpDown numericUpDownWeedInterval;
private System.Windows.Forms.Label labelWeedInterval;
private System.Windows.Forms.Label labelPatternType;
private System.Windows.Forms.ComboBox comboBoxPatternType;
private System.Windows.Forms.CheckBox checkBoxTakePhotos;
private System.Windows.Forms.FolderBrowserDialog folderBrowserDialog;
private System.Windows.Forms.GroupBox groupBoxPhotos;
```

```
        private System.Windows.Forms.Button buttonSetPhotosFolderPath;
    }
}
```

5. pielikums

Eksperimentu stenda lietotāja saskarnes galvenā loga vadības loģikas kods

```
using System;
using System.Collections.Generic;
using System.Data;
using System.Drawing;
using System.Drawing.Drawing2D;
using System.IO;
using System.Linq;
using System.Threading;
using System.Threading.Tasks;
using System.Windows.Forms;
using UR10.Patterns;
using static UR10.PatternDriver;

namespace UR10
{
   public partial class FormMain : Form, IUr10Out, IPatternDriverOut, ITcpServerOut
   {
      private IConnection connection = new Connection();
      private IPatternDriver patternDriver;
      private ISpiralBuilder spiralBuilder = new SpiralBuilder();
      private IZigZagBuilder zigZagBuilder = new ZigZagBuilder();
      private IUr10StreamDecoder decoder;
      private ITcpServer tcpServer;

      private double headXCoodrinateInPixels = 0;
      private double headYCoordinateInPixels = 0;

      private float k = 3;
      private float scale = 10;
      private int baseEllipseSize = 20;
      private int headPointerSize = 6;

      private Rectangle box1;
      private Rectangle box2;

      private List<PointF[]> executedPatternCurves = new List<PointF[]>();

      public FormMain()
      {
         InitializeComponent();

         box1 = new Rectangle((int)(50 / k), (int)(990 / k), (int)((float)Properties.Settings.Default.BoxLength / k), (int)(150 / k));
         box2 = new Rectangle((int)(50 / k), (int)(720 / k), (int)((float)Properties.Settings.Default.BoxLength / k), (int)(150 / k));

         try
         {
            checkBoxEnableRow1.Checked = Properties.Settings.Default.Row1Enabled;
            checkBoxEnableRow2.Checked = Properties.Settings.Default.Row2Enabled;
            checkBoxEnableRow3.Checked = Properties.Settings.Default.Row3Enabled;
            checkBoxEnableRow4.Checked = Properties.Settings.Default.Row4Enabled;

            numericUpDownRow1Distance.Value = Properties.Settings.Default.Row1Distance;
            numericUpDownRow2Distance.Value = Properties.Settings.Default.Row2Distance;
            numericUpDownRow3Distance.Value = Properties.Settings.Default.Row3Distance;
            numericUpDownRow4Distance.Value = Properties.Settings.Default.Row4Distance;

            numericUpDownWeedColumns.Value = Properties.Settings.Default.WeedColumns;
            numericUpDownWeedInterval.Value = Properties.Settings.Default.WeedInterval;

            if(Directory.Exists(Properties.Settings.Default.PhotosFolderPath))
            {
               folderBrowserDialog.SelectedPath = Properties.Settings.Default.PhotosFolderPath;
            }
```

```
            else
            {
                if(DialogResult.OK == folderBrowserDialog.ShowDialog())
                {
                    Properties.Settings.Default.PhotosFolderPath = folderBrowserDialog.SelectedPath;
                    Properties.Settings.Default.Save();
                }
            }
        }
        catch (Exception exc)
        {
            MessageBox.Show(exc.ToString(), "Error", MessageBoxButtons.OK, MessageBoxIcon.Error);
        }

        labelScale.Text = $"Scale 1:{scale}";
    }

    public void CommandFinished()
    {
        if (patternDriver != null)
        {
            patternDriver.CommandFinished();
        }
    }

    public void PatternCompleted()
    {
        SetControlModeButtonsState(true);
    }

    public void EmergencyStopStatusReceived(bool status)
    {
        if (patternDriver != null)
        {
            patternDriver.EmergensyStopStatusReceived(status);
        }
    }

    public void SendLogMessage(string message)
    {
        LogMessage(message);
    }

    public void CoordinatesReceived(double x, double y, double z, double rX, double rY, double rZ)
    {
        headXCoodrinateInPixels = (-x + (double)Properties.Settings.Default.BaseXCoordinate) / k;
        headYCoordinateInPixels = (-y + (double)Properties.Settings.Default.BaseYCoordinate) / k;

        if(patternDriver != null)
        {
            executedPatternCurves = patternDriver.GetExecutedPatterns().Select(p => p.Select(point => new
PointF(pictureBoxUrPlatform.Width - (-point.X * 1000 + (float)Properties.Settings.Default.BaseXCoordinate) / k, (-point.Y * 1000 +
(float)Properties.Settings.Default.BaseYCoordinate) / k)).ToArray()).ToList();
            patternDriver.UpdateCartesianData((float)x / 1000, (float)y / 1000, (float)z / 1000, (float)rX, (float)rY, (float)rZ);
        }

        Invoke((MethodInvoker)delegate
            {
                labelX.Text = $"X = {Math.Round(x, 2)}mm";
                labelY.Text = $"Y = {Math.Round(y, 2)}mm";
                labelZ.Text = $"Z = {Math.Round(z, 2)}mm";
                pictureBoxUrPlatform.Refresh();
            }
        );
    }

    private void tabControl_Selecting(object sender, TabControlCancelEventArgs e)
    {
        if(e.TabPage.Text == "Admin")
        {
```

```
            LogMessage("Admin panel access attempt");
            FormAdminPasswordPrompt formAdminPasswordPrompt = new FormAdminPasswordPrompt();
            e.Cancel = DialogResult.OK != formAdminPasswordPrompt.ShowDialog();
            if(e.Cancel)
            {
                LogMessage("Admin panel access denied");
            }
            else
            {
                LogMessage("Admin panel access granted");
            }
        }
    }

    private void buttonConnect_Click(object sender, EventArgs e)
    {
        LogMessage("Connecting to UR10. Please wait.");

        Task.Factory.StartNew(() =>
        {
            (bool isConnected, string exception) = connection.ConnectToUr10();

            if (isConnected)
            {
                LogMessage("Connected");

                LogMessage("Stoping controller program...");
                connection.SendServiceMessage("stop");
                LogMessage("Program stopped");

                LogMessage("Turning on robot...");
                connection.SendServiceMessage("power on");
                LogMessage("Power is on");

                LogMessage("Releasing brakes...");
                connection.SendServiceMessage("brake release");
                LogMessage("Brakes released");

                Stream stream = connection.GetStream();

                decoder = new Ur10StreamDecoder(this);
                Task.Factory.StartNew(() => decoder.StartDecoder(stream));

                tcpServer = new TcpServer(this);
                Task.Factory.StartNew(() => tcpServer.StartTcpServer());

                LogMessage("Starting controller program...");
                connection.SendServiceMessage("play");
                LogMessage("Program started");

                LogMessage("Waiting for TCP client");
                tcpServer.WaitForTcpClient();

                Invoke((MethodInvoker)delegate
                {
                    buttonConnect.Enabled = !isConnected;
                    buttonDisconnect.Enabled = isConnected;
                    buttonRunPattern.Enabled = isConnected;
                    buttonTransportationMode.Enabled = isConnected;
                    buttonHomeMode.Enabled = isConnected;
                    buttonStop.Enabled = isConnected;
                });

                LogMessage("TCP client connected");

                patternDriver = new PatternDriver(tcpServer, this);

                LogMessage("Turning digital and analog outputs off");
                patternDriver.TurnOffAll();
                patternDriver.SetPatternSpeed((float)Properties.Settings.Default.PatternSpeed / 1000);
```

```
        }
        else
        {
            LogMessage(exception);
        }
    });
}

private void buttonDisconnect_Click(object sender, EventArgs e)
{
    LogMessage("Disconnecting from UR10. Please wait.");

    Task.Factory.StartNew(() => tcpServer.StopTcpServer());

    Task.Factory.StartNew(() => decoder.StopDecoder());
    Thread.Sleep(1000);

    Task.Factory.StartNew(() =>
    {
        (bool isDisconnected, string exception) = connection.DisconnectFromUr10();

        Invoke((MethodInvoker)delegate
        {
            buttonConnect.Enabled = isDisconnected;
            buttonDisconnect.Enabled = !isDisconnected;
            buttonRunPattern.Enabled = !isDisconnected;
            buttonTransportationMode.Enabled = !isDisconnected;
            buttonHomeMode.Enabled = !isDisconnected;
            buttonStop.Enabled = !isDisconnected;
        });

        if (isDisconnected)
        {
            LogMessage("Disconnected");
        }
        else
        {
            LogMessage(exception);
        }
    });
}

private void LogMessage(string message)
{
    Invoke((MethodInvoker)delegate
            {
                listBoxConsole.Items.Insert(0, $"{DateTime.Now.ToLocalTime()}: {message}");
            }
    );
}

private void tabPageAdmin_Enter(object sender, EventArgs e)
{
    Task.Factory.StartNew(() => ReadSettings());
}

private void ReadSettings()
{
    try
    {
        Invoke((MethodInvoker)delegate
        {
            numericUpDownPatternStartAngle.Value = Properties.Settings.Default.PatternStartAngle;
            numericUpDownPatterDiameter.Value = Properties.Settings.Default.PatternDiameter;
            numericUpDownPatternStep.Value = Properties.Settings.Default.PatternStep;
            numericUpDownPatternSpeed.Value = Properties.Settings.Default.PatternSpeed;
            numericUpDownDeltaTheta.Value = Properties.Settings.Default.PatternDeltaTheta;
            numericUpDownBaseXCoordinate.Value = Properties.Settings.Default.BaseXCoordinate;
            numericUpDownBaseYCoordinate.Value = Properties.Settings.Default.BaseYCoordinate;
            numericUpDownTravelSpeed.Value = Properties.Settings.Default.TravelSpeed;
```

```
            textBoxIpAddress.Text = Properties.Settings.Default.IpAddress;
            numericUpDownWeedInterval.Value = Properties.Settings.Default.WeedInterval;
            comboBoxPatternType.SelectedIndex = Properties.Settings.Default.PatternType;
            checkBoxTakePhotos.Checked = Properties.Settings.Default.TakePhotos;
          });
        }
        catch(Exception exc)
        {
          MessageBox.Show(exc.ToString(), "Error", MessageBoxButtons.OK, MessageBoxIcon.Error);
        }
      }

      private void numericUpDownPatterDiameter_ValueChanged(object sender, EventArgs e)
      {
        Properties.Settings.Default.PatternDiameter = numericUpDownPatterDiameter.Value;
        Properties.Settings.Default.Save();
        pictureBoxPatternSample.Refresh();
      }

      private void numericUpDownPatternStep_ValueChanged(object sender, EventArgs e)
      {
        Properties.Settings.Default.PatternStep = numericUpDownPatternStep.Value;
        Properties.Settings.Default.Save();
        pictureBoxPatternSample.Refresh();
      }

      private void numericUpDownPatternSpeed_ValueChanged(object sender, EventArgs e)
      {
        Properties.Settings.Default.PatternSpeed = numericUpDownPatternSpeed.Value;
        Properties.Settings.Default.Save();

        if(patternDriver != null)
        {
          patternDriver.SetPatternSpeed((float)numericUpDownPatternSpeed.Value / 1000);
        }
      }

      private void checkBoxEnableRow1_CheckedChanged(object sender, EventArgs e)
      {
        Properties.Settings.Default.Row1Enabled = checkBoxEnableRow1.Checked;
        Properties.Settings.Default.Save();

        pictureBoxUrPlatform.Refresh();
        SetPatternModeButtonsState(checkBoxEnableRow1.Checked || checkBoxEnableRow2.Checked ||
checkBoxEnableRow3.Checked || checkBoxEnableRow4.Checked || Properties.Settings.Default.TakePhotos);
      }

      private void checkBoxEnableRow2_CheckedChanged(object sender, EventArgs e)
      {
        Properties.Settings.Default.Row2Enabled = checkBoxEnableRow2.Checked;
        Properties.Settings.Default.Save();

        pictureBoxUrPlatform.Refresh();
        SetPatternModeButtonsState(checkBoxEnableRow1.Checked || checkBoxEnableRow2.Checked ||
checkBoxEnableRow3.Checked || checkBoxEnableRow4.Checked || Properties.Settings.Default.TakePhotos);
      }

      private void checkBoxEnableRow3_CheckedChanged(object sender, EventArgs e)
      {
        Properties.Settings.Default.Row3Enabled = checkBoxEnableRow3.Checked;
        Properties.Settings.Default.Save();

        pictureBoxUrPlatform.Refresh();
        SetPatternModeButtonsState(checkBoxEnableRow1.Checked || checkBoxEnableRow2.Checked ||
checkBoxEnableRow3.Checked || checkBoxEnableRow4.Checked || Properties.Settings.Default.TakePhotos);
      }

      private void checkBoxEnableRow4_CheckedChanged(object sender, EventArgs e)
      {
        Properties.Settings.Default.Row4Enabled = checkBoxEnableRow4.Checked;
```

```
            Properties.Settings.Default.Save();

            pictureBoxUrPlatform.Refresh();
            SetPatternModeButtonsState(checkBoxEnableRow1.Checked || checkBoxEnableRow2.Checked || checkBoxEnableRow3.Checked || checkBoxEnableRow4.Checked || Properties.Settings.Default.TakePhotos);
        }

        private void numericUpDownRow1Distance_ValueChanged(object sender, EventArgs e)
        {
            Properties.Settings.Default.Row1Distance = numericUpDownRow1Distance.Value;
            Properties.Settings.Default.Save();
        }

        private void numericUpDownRow2Distance_ValueChanged(object sender, EventArgs e)
        {
            Properties.Settings.Default.Row2Distance = numericUpDownRow2Distance.Value;
            Properties.Settings.Default.Save();
        }

        private void numericUpDownRow3Distance_ValueChanged(object sender, EventArgs e)
        {
            Properties.Settings.Default.Row3Distance = numericUpDownRow3Distance.Value;
            Properties.Settings.Default.Save();
        }

        private void numericUpDownRow4Distance_ValueChanged(object sender, EventArgs e)
        {
            Properties.Settings.Default.Row4Distance = numericUpDownRow4Distance.Value;
            Properties.Settings.Default.Save();
        }

        private void numericUpDownDeltaTheta_ValueChanged(object sender, EventArgs e)
        {
            Properties.Settings.Default.PatternDeltaTheta = numericUpDownDeltaTheta.Value;
            Properties.Settings.Default.Save();
            pictureBoxPatternSample.Refresh();
        }

        private void numericUpDownPatternStartAngle_ValueChanged(object sender, EventArgs e)
        {
            Properties.Settings.Default.PatternStartAngle = numericUpDownPatternStartAngle.Value;
            Properties.Settings.Default.Save();
            pictureBoxPatternSample.Refresh();
        }

        private void NumericUpDownBaseXCoordinate_ValueChanged(object sender, EventArgs e)
        {
            Properties.Settings.Default.BaseXCoordinate = numericUpDownBaseXCoordinate.Value;
            Properties.Settings.Default.Save();
        }

        private void NumericUpDownBaseYCoordinate_ValueChanged(object sender, EventArgs e)
        {
            Properties.Settings.Default.BaseYCoordinate = numericUpDownBaseYCoordinate.Value;
            Properties.Settings.Default.Save();
        }

        private void PictureBoxUrPlatform_Paint(object sender, PaintEventArgs e)
        {
            e.Graphics.Clear(pictureBoxUrPlatform.BackColor = Color.White);
            e.Graphics.SmoothingMode = SmoothingMode.AntiAlias;

            e.Graphics.FillEllipse(Brushes.SkyBlue, pictureBoxUrPlatform.Width - (float)Properties.Settings.Default.BaseXCoordinate / k - baseEllipseSize/2, (float)Properties.Settings.Default.BaseYCoordinate / k - baseEllipseSize/2, baseEllipseSize, baseEllipseSize);
            e.Graphics.FillEllipse(Brushes.Blue, pictureBoxUrPlatform.Width - (float)headXCoodrinateInPixels - headPointerSize/2, (float)(headYCoordinateInPixels - headPointerSize/2), headPointerSize, headPointerSize);

            for(int x = 0; x < executedPatternCurves.Count; x++)
            {
                if (executedPatternCurves[x].Length > 2)
```

```
            {
                e.Graphics.DrawLines(Pens.Blue, executedPatternCurves[x]);
            }
        }

        if(Properties.Settings.Default.Row1Enabled || Properties.Settings.Default.Row2Enabled)
        {
            e.Graphics.DrawRectangle(Pens.OrangeRed, box1);
        }

        if (Properties.Settings.Default.Row3Enabled || Properties.Settings.Default.Row4Enabled)
        {
            e.Graphics.DrawRectangle(Pens.OrangeRed, box2);
        }
    }

    //Code from http://csharphelper.com/blog/2018/10/draw-an-archimedes-spiral-in-c/
    private void pictureBoxPatternSample_Paint(object sender, PaintEventArgs e)
    {
        e.Graphics.Clear(pictureBoxPatternSample.BackColor = Color.White);
        e.Graphics.SmoothingMode = SmoothingMode.AntiAlias;
        try
        {
            float a = (float)Properties.Settings.Default.PatternStep / 1000 * scale;
            float startAngle = (float)Properties.Settings.Default.PatternStartAngle / 57.3F;

            // Center point.
            PointF center = new PointF(pictureBoxPatternSample.ClientSize.Width / 2, pictureBoxPatternSample.ClientSize.Height / 2);
            PointF centerInMm = new PointF(pictureBoxPatternSample.ClientSize.Width / 2 * k / 1000,
pictureBoxPatternSample.ClientSize.Height / 2 * k / 1000);

            // Draw axes.
            e.Graphics.DrawLine(Pens.Black, center.X, 0, center.X, pictureBoxPatternSample.ClientSize.Height);
            e.Graphics.DrawLine(Pens.Black, 0, center.Y, pictureBoxPatternSample.ClientSize.Width, center.Y);

            float maxRadius = (float)Properties.Settings.Default.PatternDiameter / 1000 / 2 * scale;

            List<PointF> points = new List<PointF>();

            switch (Properties.Settings.Default.PatternType)
            {
                case (int)PatternType.Spiral:
                    points = spiralBuilder.GetSpiralPoints(centerInMm, a, startAngle, maxRadius).Select(p => new
PointF(pictureBoxPatternSample.ClientSize.Width - p.X * 1000 / 3, p.Y * 1000 / 3)).ToList();
                    break;

                case (int)PatternType.ZigZag:
                    points = zigZagBuilder.GetZigZagPoints(centerInMm, a, maxRadius * 2).Select(p => new PointF(p.X * 1000 / 3, p.Y *
1000 / 3)).ToList();
                    break;
            }

            e.Graphics.DrawLines(Pens.Red, points.ToArray());
        }
        catch (Exception ex)
        {
            MessageBox.Show(ex.Message);
        }
    }

    private void ButtonRunPattern_Click(object sender, EventArgs e)
    {
        Task.Factory.StartNew(() => patternDriver.RunConfiguredPattern());
        SetControlModeButtonsState(false);
    }

    private void SetControlModeButtonsState(bool enabled)
    {
        Invoke((MethodInvoker)delegate
        {
```

```
            SetPatternModeButtonsState(enabled);
            SetTransportationModeButtonsState(enabled);
        });
    }

    private void SetTransportationModeButtonsState(bool enabled)
    {
        Invoke((MethodInvoker)delegate
        {
            buttonTransportationMode.Enabled = enabled;
            buttonHomeMode.Enabled = enabled;
        });
    }

    private void SetPatternModeButtonsState(bool enabled)
    {
        if (this.Handle != null && patternDriver != null)
        {
            Invoke((MethodInvoker)delegate
            {
                buttonRunPattern.Enabled = enabled;
            });
        }
    }

    private void NumericUpDownTravelSpeed_ValueChanged(object sender, EventArgs e)
    {
        Properties.Settings.Default.TravelSpeed = numericUpDownTravelSpeed.Value;
        Properties.Settings.Default.Save();
    }

    private void ButtonTransportationMode_Click(object sender, EventArgs e)
    {
        LogMessage("Transportation mode initiated");
        Task.Factory.StartNew(() => patternDriver.RunTransportationModePattern());
        SetControlModeButtonsState(false);
    }

    private void TextBoxIpAddress_Leave(object sender, EventArgs e)
    {
        Properties.Settings.Default.IpAddress = textBoxIpAddress.Text;
        Properties.Settings.Default.Save();
    }

    private void ButtonHomeMode_Click(object sender, EventArgs e)
    {
        LogMessage("Home mode initiated");
        Task.Factory.StartNew(() => patternDriver.RunHomeModePattern());
        SetControlModeButtonsState(false);
    }

    private void ButtonStop_Click(object sender, EventArgs e)
    {
        LogMessage("Stop All initiated");
        Task.Factory.StartNew(() => patternDriver.StopAll());
        buttonRunPattern.Enabled = true;
        buttonTransportationMode.Enabled = true;
        buttonHomeMode.Enabled = true;
    }

    private void buttonReset_Click(object sender, EventArgs e)
    {
        Properties.Settings.Default.Reset();
        ReadSettings();
    }

    private void numericUpDownWeedColumns_Validating(object sender, System.ComponentModel.CancelEventArgs e)
    {
        if (numericUpDownWeedColumns.Value * numericUpDownWeedInterval.Value > Properties.Settings.Default.BoxLength)
        {
```

```
                MessageBox.Show($"Multiplication of Weed columns and Interval must not exceed weed box length: {Properties.Settings.Default.BoxLength}", "Warning", MessageBoxButtons.OK, MessageBoxIcon.Warning);
                e.Cancel = true;
            }
            else
            {
                Properties.Settings.Default.WeedColumns = numericUpDownWeedColumns.Value;
                Properties.Settings.Default.Save();
            }
        }

        private void numericUpDownWeedInterval_Validating(object sender, System.ComponentModel.CancelEventArgs e)
        {
            if (numericUpDownWeedColumns.Value * numericUpDownWeedInterval.Value > Properties.Settings.Default.BoxLength)
            {
                MessageBox.Show($"Multiplication of Weed columns and Interval must not exceed weed box length: {Properties.Settings.Default.BoxLength}", "Warning", MessageBoxButtons.OK, MessageBoxIcon.Warning);
                e.Cancel = true;
            }
            else
            {
                Properties.Settings.Default.WeedInterval = numericUpDownWeedInterval.Value;
                Properties.Settings.Default.Save();
            }
        }

        private void checkBoxTakePhotos_CheckedChanged(object sender, EventArgs e)
        {
            Properties.Settings.Default.TakePhotos = checkBoxTakePhotos.Checked;
            Properties.Settings.Default.Save();

            SetPatternModeButtonsState(checkBoxTakePhotos.Checked);
        }

        private void comboBoxPatternType_SelectedIndexChanged(object sender, EventArgs e)
        {
            Properties.Settings.Default.PatternType = comboBoxPatternType.SelectedIndex;
            Properties.Settings.Default.Save();

            if(comboBoxPatternType.SelectedIndex == (int)PatternType.Spiral)
            {
                numericUpDownPatternStartAngle.Enabled = true;
                numericUpDownDeltaTheta.Enabled = true;
            }
            else
            {
                numericUpDownPatternStartAngle.Enabled = false;
                numericUpDownDeltaTheta.Enabled = false;
            }

            pictureBoxPatternSample.Refresh();
        }

        private void buttonSetPhotosFolderPath_Click(object sender, EventArgs e)
        {
            if (DialogResult.OK == folderBrowserDialog.ShowDialog())
            {
                Properties.Settings.Default.PhotosFolderPath = folderBrowserDialog.SelectedPath;
                Properties.Settings.Default.Save();
            }
        }
    }
}
```

6. pielikums

Eksperimentu stenda datorprogrammas TCP servera kods

```
using System;
using System.Collections.Generic;
using System.Diagnostics;
using System.Linq;
using System.Net;
using System.Net.Sockets;
using System.Text;
using System.Threading;
using System.Threading.Tasks;

namespace UR10
{
    public interface ITcpServerOut
    {
        void CommandFinished();
    }

    public interface ITcpServer
    {
        void StartTcpServer();
        void StopTcpServer();
        void SendMoveP(float[] position, float speed);
        void SendDigitalOutOn();
        void SendDigitalOutOff();
        void SendAnalogOutOn(float voltage);
        void SendAnalogOutOff();
        void SendStopL();
        void WaitForTcpClient();
        void SendMoveL(float[] position, float speed);
        void StorePositionPoint(float[] position);
        void ExecuteStoredMoveP();
        void ExecuteStoredMoveL();
        void SetPatternSpeed(float speed);
    }

    class TcpServer : ITcpServer
    {
        bool stopServer = false;
        TcpListener server = new TcpListener(IPAddress.Any, 888);
        NetworkStream stream;
        ITcpServerOut serverUser;
        TcpClient client;

        public TcpServer(ITcpServerOut serverUser)
        {
            this.serverUser = serverUser;
        }

        public void StartTcpServer()
        {
            server.Start();

            while(!stopServer)
            {
                client = server.AcceptTcpClient();
                stream = client.GetStream();

                while (client.Connected)
                {
                    byte[] arrayBytesRequest = new byte[client.Available];
                    int nRead = stream.Read(arrayBytesRequest, 0, arrayBytesRequest.Length);
```

```
            if (nRead > 0)
            {
                string message = Encoding.ASCII.GetString(arrayBytesRequest);

                if(message == "command_finished")
                {
                    serverUser.CommandFinished();
                }
            }
            else
            {
                if (client.Available == 0)
                {
                    stream.Close();
                }
            }

            Thread.Sleep(1);
        }

        Thread.Sleep(1);
    }
}

public void WaitForTcpClient()
{
    while(client == null)
    {
        Thread.Sleep(1000);
    }
}

public void StopTcpServer()
{
    stopServer = false;
    server.Stop();
}

public void SendMoveP(float[] position, float speed)
{
    byte[] data = Encoding.ASCII.GetBytes($"({(float)CommandType.MoveP},{string.Join(",", position)},{speed})\n");
    stream.Write(data, 0, data.Length);
}

public void SendMoveL(float[] position, float speed)
{
    byte[] data = Encoding.ASCII.GetBytes($"({(float)CommandType.MoveL},{string.Join(",", position)},{speed})\n");
    stream.Write(data, 0, data.Length);
}

public void SendDigitalOutOn()
{
    byte[] data = Encoding.ASCII.GetBytes($"({(float)CommandType.DigitalOut_0},1)\n");
    stream.Write(data, 0, data.Length);
}

public void SendDigitalOutOff()
{
    byte[] data = Encoding.ASCII.GetBytes($"({(float)CommandType.DigitalOut_0},0)\n");
    stream.Write(data, 0, data.Length);
}

public void SendAnalogOutOn(float voltage)
{
    byte[] data = Encoding.ASCII.GetBytes($"({(float)CommandType.AnalogOut_0},{voltage * 0.1})\n");
    stream.Write(data, 0, data.Length);
}

public void SendAnalogOutOff()
```

```
        {
            byte[] data = Encoding.ASCII.GetBytes($"({(float)CommandType.AnalogOut_0},0)\n");
            stream.Write(data, 0, data.Length);
        }

        public void SendStopL()
        {
            byte[] data = Encoding.ASCII.GetBytes($"({(float)CommandType.StopL})\n");
            stream.Write(data, 0, data.Length);
        }

        public void StorePositionPoint(float[] position)
        {
            byte[] data = Encoding.ASCII.GetBytes($"({(float)CommandType.StorePositionPoint},{string.Join(",", position)})\n");
            stream.Write(data, 0, data.Length);
        }

        public void ExecuteStoredMoveP()
        {
            byte[] data = Encoding.ASCII.GetBytes($"({(float)CommandType.ExecuteStoredMoveP})\n");
            stream.Write(data, 0, data.Length);
        }

        public void ExecuteStoredMoveL()
        {
            byte[] data = Encoding.ASCII.GetBytes($"({(float)CommandType.ExecuteStoredMoveL})\n");
            stream.Write(data, 0, data.Length);
        }

        public void SetPatternSpeed(float speed)
        {
            byte[] data = Encoding.ASCII.GetBytes($"({(float)CommandType.SetPatternSpeed},{speed})\n");
            stream.Write(data, 0, data.Length);
        }

        private enum CommandType
        {
            MoveP,
            DigitalOut_0,
            AnalogOut_0,
            StopL,
            MoveL,
            StorePositionPoint,
            ExecuteStoredMoveP,
            SetPatternSpeed,
            ExecuteStoredMoveL
        }
    }
}
```

7. pielikums

Eksperimentu stenda zig-zag šablona koordinātu punktu būvēšanas kods

```
using System;
using System.Collections.Generic;
using System.Drawing;
using System.Linq;
using System.Text;
using System.Threading.Tasks;

namespace UR10.Patterns
{
        public interface IZigZagBuilder
        {
    List<PointF> GetZigZagPoints(PointF center, float step, float maxWidth);
        }
        class ZigZagBuilder: IZigZagBuilder
        {
        public List<PointF> GetZigZagPoints(PointF center, float step, float maxWidth)
        {
        float startX = center.X - maxWidth / 2;
        float startY = center.Y - maxWidth / 2;
        float endY = startY + maxWidth;

        float columns = maxWidth / step;

      List<PointF> zigZagPoints = new List<PointF>();

      for(int q = 0; q <= columns; q++)
        {
       float nextX = startX + q * step;
       zigZagPoints.Add( new PointF(nextX, startY));
       zigZagPoints.Add(new PointF(nextX, endY));
        }

      return zigZagPoints;
        }
        }
}
```

8. pielikums

Eksperimentu stenda spirāles šablona koordinātu punktu būvēšanas kods

```
using System;
using System.Collections.Generic;
using System.Drawing;

namespace UR10.Patterns
{
    public interface ISpiralBuilder
    {
        List<PointF> GetSpiralPoints(PointF center, float a, float angleOffset, float maxRadius);
    }

    //Code from http://csharphelper.com/blog/2018/10/draw-an-archimedes-spiral-in-c/
    class SpiralBuilder : ISpiralBuilder
    {
        // Return points that define a spiral.
        public List<PointF> GetSpiralPoints(PointF center, float a, float angleOffset, float maxRadius)
        {
            // Get the points.
            List<PointF> points = new List<PointF>();
            float dtheta = (float)((double)Properties.Settings.Default.PatternDeltaTheta * Math.PI / 180);
            for (float theta = 0; ; theta += dtheta)
            {
                // Calculate r.
                float r = a * theta;

                // Convert to Cartesian coordinates.
                float x, y;
                PolarToCartesian(r, theta + angleOffset, out x, out y);

                // Center.
                x += center.X;
                y += center.Y;

                // Create the point.
                points.Add(new PointF((float)x, (float)y));

                // If we have gone far enough, stop.
                if (r >= maxRadius) break;
            }
            return points;
        }

        // Convert polar coordinates into Cartesian coordinates.
        private void PolarToCartesian(float r, float theta, out float x, out float y)
        {
            x = (float)(r * Math.Cos(theta));
            y = (float)(r * Math.Sin(theta));
        }
    }
}
```

9. pielikums

Eksperimentu stenda šablonu pārvaldnieka kods

```
using System;
using System.Collections.Generic;
using System.Drawing;
using System.Threading;
using UR10.Patterns;

namespace UR10
{
    public interface IPatternDriverOut
    {
        void SendLogMessage(string message);
        void PatternCompleted();
    }

    public interface IPatternDriver
    {
        void RunConfiguredPattern();
        void EmergensyStopStatusReceived(bool status);
        void TurnOffAll();
        List<List<PointF>> GetExecutedPatterns();
        void RunTransportationModePattern();
        void RunHomeModePattern();
        void StopAll();
        void UpdateCartesianData(float x, float y, float z, float rX, float rY, float rZ);
        void CommandFinished();
        void SetPatternSpeed(float speed);
    }

    public class PatternDriver : IPatternDriver
    {
        private const float OutputVoltage = 10;
        private List<List<PointF>> executedPatterns = new List<List<PointF>>();

        private float actualX;
        private float actualY;
        private float actualZ;

        private float actualRX;
        private float actualRY;
        private float actualRZ;

        private const float HomeX = 0.16F;
        private const float HomeY = -0.22F;
        private const float HomeZ = 0.4F;

        private const float TransportationX = -0.43F;
        private const float TransportationY = -0.18F;
        private const float TransportationZ = 0.4F;

        //darba virsmas koordinates pret bazi
        //xy xy
        //01 11
        //00 10

        private const float ZMin = 0.4F;
        private const float ZMax = 0.6F;

        private const float X00 = 0.26F;
        private const float Y00 = -0.18F;

        private const float X10 = -0.6F;
```

```
private const float Y01 = -0.9F;

private const float xOffset = 0.04F;
private bool emergencyStoped = false;
private bool stopAll = false;
private IPatternDriverOut patternDriverUser;
private ISpiralBuilder spiralBuilder = new SpiralBuilder();
private IZigZagBuilder zigZagBuilder = new ZigZagBuilder();
private IPhotoCapturer photoCapturer = new PhotoCapturer();
private IAnnotationParser annotationParser = new AnnotationParser();
private ITcpServer tcpServer;
private bool commandFinished = false;
private bool executingPattern = false;

private List<string> sharedFileName = null;

public PatternDriver(ITcpServer tcpServer, IPatternDriverOut patternDriverUser)
{
   this.tcpServer = tcpServer;
   this.patternDriverUser = patternDriverUser;
}

public void CommandFinished()
{
   commandFinished = true;
}

public void EmergensyStopStatusReceived(bool status)
{
   emergencyStoped = status;
}

public void UpdateCartesianData(float x, float y, float z, float rX, float rY, float rZ)
{
   actualX = x;
   actualY = y;
   actualZ = z;

   actualRX = ConvertToDegrees(rX);
   actualRY = ConvertToDegrees(rY);
   actualRZ = ConvertToDegrees(rZ);

   if(executingPattern)
   {
      executedPatterns[executedPatterns.Count - 1].Add(new PointF(actualX, actualY));
   }
}

public void StopAll()
{
   stopAll = true;
   tcpServer.SendStopL();
   TurnOffAll();
}

public void RunConfiguredPattern()
{
   if (!Properties.Settings.Default.Row1Enabled &&
         !Properties.Settings.Default.Row2Enabled &&
         !Properties.Settings.Default.Row3Enabled &&
         !Properties.Settings.Default.Row4Enabled &&
         !Properties.Settings.Default.TakePhotos)
   {
      return;
   }

   executedPatterns.Clear();

   try
```

```
                        {
                            CapturePhotos();

                            if(Properties.Settings.Default.TakePhotos)
                            {

                                List<BoundingBox> detectedWeedBoundingBoxes = annotationParser.ParseAnnotations(sharedFileName);
                                patternDriverUser.SendLogMessage($"Annotation parser retrieved {detectedWeedBoundingBoxes.Count} weed bounding
boxes");

                                tcpServer.SendDigitalOutOn();
                                WaitTillCommandFinished();

                                for (int box = 0; box < detectedWeedBoundingBoxes.Count; box++)
                                {
                                    patternDriverUser.SendLogMessage($"Processing box No {box}...");

                                    switch (Properties.Settings.Default.PatternType)
                                    {
                                        case (int)PatternType.Spiral:
                                            patternDriverUser.SendLogMessage($"Single spiral pattern is not implemented for box processing.");
                                            break;

                                        case (int)PatternType.ZigZag:
                                            RunZigZagPatternSingle(detectedWeedBoundingBoxes[box]);
                                            break;
                                    }
                                }
                            }
                            else
                            {
                                tcpServer.SendDigitalOutOn();
                                WaitTillCommandFinished();

                                if (Properties.Settings.Default.Row1Enabled)
                                {
                                    switch (Properties.Settings.Default.PatternType)
                                    {
                                        case (int)PatternType.Spiral:
                                            RunSpiralPattern((float)Properties.Settings.Default.Row1Distance,
(float)Properties.Settings.Default.WeedInterval / 1000);
                                            break;

                                        case (int)PatternType.ZigZag:
                                            RunZigZagPattern((float)Properties.Settings.Default.Row1Distance,
(float)Properties.Settings.Default.WeedInterval / 1000);
                                            break;
                                    }
                                }

                                if (Properties.Settings.Default.Row2Enabled)
                                {
                                    switch (Properties.Settings.Default.PatternType)
                                    {
                                        case (int)PatternType.Spiral:
                                            RunSpiralPattern((float)Properties.Settings.Default.Row2Distance,
(float)Properties.Settings.Default.WeedInterval / 1000);
                                            break;

                                        case (int)PatternType.ZigZag:
                                            RunZigZagPattern((float)Properties.Settings.Default.Row2Distance,
(float)Properties.Settings.Default.WeedInterval / 1000);
                                            break;
                                    }
                                }

                                if (Properties.Settings.Default.Row3Enabled)
                                {
                                    switch (Properties.Settings.Default.PatternType)
                                    {
```

```
                    case (int)PatternType.Spiral:
                        RunSpiralPattern((float)Properties.Settings.Default.Row3Distance,
(float)Properties.Settings.Default.WeedInterval / 1000);
                        break;

                    case (int)PatternType.ZigZag:
                        RunZigZagPattern((float)Properties.Settings.Default.Row3Distance,
(float)Properties.Settings.Default.WeedInterval / 1000);
                        break;
                }
            }

            if (Properties.Settings.Default.Row4Enabled)
            {
                switch (Properties.Settings.Default.PatternType)
                {
                    case (int)PatternType.Spiral:
                        RunSpiralPattern((float)Properties.Settings.Default.Row4Distance,
(float)Properties.Settings.Default.WeedInterval / 1000);
                        break;

                    case (int)PatternType.ZigZag:
                        RunZigZagPattern((float)Properties.Settings.Default.Row4Distance,
(float)Properties.Settings.Default.WeedInterval / 1000);
                        break;
                }
            }
        }

        tcpServer.SendDigitalOutOff();
        WaitTillCommandFinished();

        //CapturePhotos();

        RunHomeModePattern();
    }
    catch (Exception e)
    {
        patternDriverUser.SendLogMessage("System exception. Executing emergency Laser turn off and Go home commands");
        TurnOffAll();
        RunHomeModePattern();
    }
}
public void TurnOffAll()
{
    tcpServer.SendDigitalOutOff();
    WaitTillCommandFinished();
    tcpServer.SendAnalogOutOff();
    WaitTillCommandFinished();
}

public List<List<PointF>> GetExecutedPatterns()
{
    return executedPatterns;
}

public void RunTransportationModePattern()
{
    string error = SendMoveLCommand(TransportationX, TransportationY, TransportationZ,
Properties.Settings.Default.TravelSpeed / 1000, 180, 0, 0);

    if (string.IsNullOrEmpty(error))
    {
        WaitTillCommandFinished();

        patternDriverUser.SendLogMessage("Transportation mode enabled");
        patternDriverUser.PatternCompleted();
    }
    else
    {
```

```
            patternDriverUser.SendLogMessage(error);
        }
    }

    public void RunHomeModePattern()
    {
        string error = SendMoveLCommand(HomeX, HomeY, HomeZ, Properties.Settings.Default.TravelSpeed / 1000, 180, 0, 0);

        if (string.IsNullOrEmpty(error))
        {
            WaitTillCommandFinished();

            patternDriverUser.SendLogMessage("Home mode enabled");
            patternDriverUser.PatternCompleted();
        }
        else
        {
            patternDriverUser.SendLogMessage(error);
        }
    }

    public void SetPatternSpeed(float speed)
    {
        string error = SendSetPatternSpeedCommand(speed);
        if (string.IsNullOrEmpty(error))
        {
            WaitTillCommandFinished();

            patternDriverUser.SendLogMessage("Pattern speed is set");
        }
        else
        {
            patternDriverUser.SendLogMessage(error);
        }
    }

    public enum PatternType
    {
        Spiral,
        ZigZag
    }

    private List<PointF> CalculateSpiralPattern(PointF center)
    {
        float a = (float)Properties.Settings.Default.PatternStep / 1000;
        float startAngle = (float)Properties.Settings.Default.PatternStartAngle / 57.3F;
        float maxRadius = (float)Properties.Settings.Default.PatternDiameter / 1000 / 2;

        return spiralBuilder.GetSpiralPoints(center, a, startAngle, maxRadius);
    }

    private List<PointF> CalculateZigZagPattern(PointF center, float maxWidth = 0, float maxHeight = 0)
    {
        float step = (float)Properties.Settings.Default.PatternStep / 1000;
        maxWidth = maxWidth == 0 ? (float)Properties.Settings.Default.PatternDiameter / 1000 : maxWidth / 1000;

        return zigZagBuilder.GetZigZagPoints(center, step, maxWidth, maxHeight / 1000);
    }

    private bool RunSpiralPattern(float y, float xStep)
    {
        for (int column = 0; column < Properties.Settings.Default.WeedColumns; column++)
        {
            float xCenter = X00 - column * xStep - xOffset;
            float yCenter = y / 1000;

            bool isSpiralCenterReached = TravelToCoordinate(new PointF(xCenter, yCenter));

            if (isSpiralCenterReached)
            {
```

```
            List<PointF> points = CalculateSpiralPattern(new PointF(xCenter, yCenter));
            executedPatterns.Add(new List<PointF>());
            bool patternCompleted = RunPatterByPoints(points, CommandType.MoveP);

            if (!patternCompleted)
            {
                return false;
            }
        }
        else
        {
            return false;
        }
    }

    return true;
}

private bool RunZigZagPattern(float y, float xStep)
{
    for (int column = 0; column < Properties.Settings.Default.WeedColumns; column++)
    {
        float xCorner = X00 - column * xStep - xOffset + (float)Properties.Settings.Default.PatternDiameter / 2 / 1000;
        float yCorner = y / 1000 + (float)Properties.Settings.Default.PatternDiameter / 2 / 1000;

        bool isZigZagCornerReached = TravelToCoordinate(new PointF(xCorner, yCorner));

        if (isZigZagCornerReached)
        {
            List<PointF> points = CalculateZigZagPattern(
                new PointF(
                    xCorner - (float)Properties.Settings.Default.PatternDiameter / 2 / 1000,
                    yCorner - (float)Properties.Settings.Default.PatternDiameter / 2/ 1000)
                );
            executedPatterns.Add(new List<PointF>());
            bool patternCompleted = RunPatterByPoints(points, CommandType.MoveL);

            if (!patternCompleted)
            {
                return false;
            }
        }
        else
        {
            return false;
        }
    }

    return true;
}

private bool RunZigZagPatternSingle(BoundingBox box)
{
    float xCorner = ((float)Properties.Settings.Default.BaseXCoordinate + box.Xmin) / 1000;
    float yCorner = ((float)Properties.Settings.Default.BaseYCoordinate + box.Ymin) / 1000;

    bool isZigZagCornerReached = TravelToCoordinate(new PointF(xCorner, yCorner));

    if (isZigZagCornerReached)
    {
        List<PointF> points = CalculateZigZagPattern(
            new PointF(
                xCorner - (box.Xmin - box.Xmax) / 2 / 1000,
                yCorner + (box.Ymax - box.Ymin)/2/1000),
            box.Xmin-box.Xmax,
            box.Ymax-box.Ymin
            );
        executedPatterns.Add(new List<PointF>());
        bool patternCompleted = RunPatterByPoints(points, CommandType.MoveL);
```

```
            if (!patternCompleted)
            {
                return false;
            }
        }
        else
        {
            return false;
        }

        return true;
    }

    private bool CapturePhotos()
    {
        if (Properties.Settings.Default.TakePhotos)
        {
            sharedFileName = new List<string>();

            float x = -0.58F;
            float y = -0.72F;
            float z = 0.45F;

            float xStep = 0.26F;
            float yStep = 0.25F;

            float rX = 127;
            float rY = 0;
            float rZ = 127;

            int maxRowIndex = Properties.Settings.Default.Row3Enabled || Properties.Settings.Default.Row4Enabled ? 2 : 1;
            int currentRowIndex = Properties.Settings.Default.Row1Enabled || Properties.Settings.Default.Row2Enabled ? 0 : 1;

            for (int row = currentRowIndex; row < maxRowIndex; row++)
            {
                for (int col = 0; col < 3; col++)
                {
                    float xx = x + col * xStep;
                    float yy = y + row * yStep;

                    string error = SendMoveLCommand(xx, yy, z, Properties.Settings.Default.TravelSpeed / 1000, rX, rY, rZ);

                    if (string.IsNullOrEmpty(error))
                    {
                        WaitTillCommandFinished();

                        patternDriverUser.SendLogMessage($"Photo position x={x} y={y} z={z} reached. Capturing photo");
                        (string output, string errors) = photoCapturer.CapturePhoto();

                        if (string.IsNullOrEmpty(errors))
                        {
                            patternDriverUser.SendLogMessage(output);

                            //string moved = photoCapturer.OrganizePhotoFiles(DateTime.Now.ToShortDateString().Replace("/", "-"));
                            string movedFileName = photoCapturer.OrganizePhotoFiles(Properties.Settings.Default.PhotosFolderPath, col +
row * 3);

                            if (movedFileName.StartsWith("Error:"))
                            {
                                patternDriverUser.SendLogMessage(movedFileName);
                                return false;
                            }
                            else
                            {
                                sharedFileName.Add(movedFileName);
                            }
                        }
                        else
                        {
                            patternDriverUser.SendLogMessage(errors);
```

```
                    return false;
                }
            }
            else
            {
                patternDriverUser.SendLogMessage(error);
                return false;
            }
        }
    }
}

    return true;
}

private bool TravelToCoordinate(PointF center)
{
    patternDriverUser.SendLogMessage("Traveling to coordinate");

    string error = SendMoveLCommand(center.X, center.Y, HomeZ, Properties.Settings.Default.TravelSpeed / 1000, 180, 0, 0);

    if (string.IsNullOrEmpty(error))
    {
        WaitTillCommandFinished();

        patternDriverUser.SendLogMessage("Coordinate is reached");
        return true;
    }
    else
    {
        patternDriverUser.SendLogMessage(error);
        return false;
    }
}

private bool RunPatterByPoints(List<PointF> points, CommandType type)
{
    string error = null;

    patternDriverUser.SendLogMessage("Pattern started");

    for (int x = 0; x < points.Count; x++)
    {
        error = StorePositionPoint(points[x].X, points[x].Y, ZMin, 180, 0, 0);

        if (string.IsNullOrEmpty(error))
        {
            WaitTillCommandFinished();
        }
        else
        {
            patternDriverUser.SendLogMessage(error);
            return false;
        }
    }

    tcpServer.SendAnalogOutOn(OutputVoltage);
    WaitTillCommandFinished();

    executingPattern = true;

    if (type == CommandType.MoveP)
    {
        tcpServer.ExecuteStoredMoveP();
    }
    else if (type == CommandType.MoveL)
    {
        tcpServer.ExecuteStoredMoveL();
    }
```

```
    WaitTillCommandFinished();
    executingPattern = false;

    tcpServer.SendAnalogOutOff();
    WaitTillCommandFinished();

    if (string.IsNullOrEmpty(error))
    {
        patternDriverUser.SendLogMessage("Pattern completed");
    }
    return true;
}

private string SendMoveLCommand(float x, float y, float z, decimal speed, float rX, float rY, float rZ)
{
    if (stopAll)
    {
        return "Stop";
    }

    if (x <= X00 && x >= X10 && y <= Y00 && y >= Y01 && z >= ZMin && z <= ZMax && speed <= 0.2M)
    {
        tcpServer.SendMoveL(new float[] { x, y, z, ConvertToRadians(rX), ConvertToRadians(rY), ConvertToRadians(rZ) },
(float)speed);

        return null;
    }
    else
    {
        return $"Bad movel command. x={x}, y={y}, z={z}, speed={speed}";
    }
}

private string SendSetPatternSpeedCommand(float speed)
{
    if (stopAll)
    {
        return "Stop";
    }

    if (speed <= 0.2F)
    {
        tcpServer.SetPatternSpeed(speed);
        return null;
    }
    else
    {
        return $"Bad set pattern speed command. Speed={speed}";
    }
}

private string SendMovePCommand(float x, float y, float z, decimal speed, float rX, float rY, float rZ)
{
    if (stopAll)
    {
        return "Stop";
    }

    if (x <= X00 && x >= X10 && y <= Y00 && y >= Y01 && z >= ZMin && z <= ZMax && speed <= 0.2M)
    {
        tcpServer.SendMoveP(new float[] { x, y, z, ConvertToRadians(rX), ConvertToRadians(rY), ConvertToRadians(rZ) },
(float)speed);

        return null;
    }
    else
    {
        return $"Bad movep command. x={x}, y={y}, z={z}, speed={speed}";
    }
}

private string StorePositionPoint(float x, float y, float z, float rX, float rY, float rZ)
```

```
        {
            if (stopAll)
            {
                return "Stop";
            }

            if (x <= X00 && x >= X10 && y <= Y00 && y >= Y01 && z >= ZMin && z <= ZMax)
            {
                tcpServer.StorePositionPoint(new float[] { x, y, z, ConvertToRadians(rX), ConvertToRadians(rY), ConvertToRadians(rZ) });
                return null;
            }
            else
            {
                return $"Bad store movep command. x={x}, y={y}, z={z}";
            }
        }

        private float ConvertToRadians(double angle)
        {
            return (float)(Math.PI / 180 * angle);
        }

        private float ConvertToDegrees(double angle)
        {
            return (float)(angle * 180 / Math.PI);
        }

        private void WaitTillCommandFinished()
        {
            while (!commandFinished)
            {
                Thread.Sleep(1);
            }
            commandFinished = false;
        }

        private enum CommandType
        {
            MoveL,
            MoveP
        }
    }
}
```

10. pielikums

GPS RTK eksperimeta testu žurnālfailu saturs

krustojums ozolu osu cels.txt

```
16:53:36  $GNRMC,165336.00,A,5639.83144,N,02340.97291,E,0.005,,100919,,,R,V*04
16:53:36  $GNVTG,,T,,M,0.005,N,0.009,K,D*34
16:53:36  $GNGGA,165336.00,5639.83144,N,02340.97291,E,4,12,0.54,-0.5,M,23.7,M,1.0,0000*42
16:53:36  $GNGSA,A,3,03,07,06,09,23,26,02,16,,,,,1.08,0.54,0.94,1*0F
16:53:36  $GNGSA,A,3,80,79,69,71,87,70,,,,,,,1.08,0.54,0.94,2*00
16:53:36  $GNGSA,A,3,07,12,30,19,33,27,11,,,,,,1.08,0.54,0.94,3*0C
16:53:36  $GNGSA,A,3,19,22,20,07,,,,,,,,,1.08,0.54,0.94,4*0C
16:53:36  $GPGSV,3,1,10,02,31,303,34,03,22,136,45,06,40,244,40,07,34,192,36,1*6D
16:53:36  $GPGSV,3,2,10,09,81,241,54,16,24,081,34,23,60,089,49,26,23,050,44,1*66
16:53:36  $GPGSV,3,3,10,29,09,358,41,30,04,206,34,1*68
16:53:36  $GPGSV,3,1,10,02,31,303,,03,22,136,40,06,40,244,34,07,34,192,36,6*6B
16:53:36  $GPGSV,3,2,10,09,81,241,47,16,24,081,,23,60,089,,26,23,050,40,6*6D
16:53:36  $GPGSV,3,3,10,29,09,358,37,30,04,206,24,6*6F
16:53:36  $GLGSV,3,1,11,69,17,104,47,70,75,079,45,71,46,297,39,72,00,290,,1*73
16:53:36  $GLGSV,3,2,11,73,08,175,33,79,38,042,45,80,52,126,45,85,00,227,24,1*73
16:53:36  $GLGSV,3,3,11,86,28,274,48,87,24,339,46,1*73
16:53:36  $GLGSV,3,1,10,69,17,104,35,70,75,079,,71,46,297,30,72,00,290,,3*7D
16:53:36  $GLGSV,3,2,10,73,08,175,31,79,38,042,41,80,52,126,38,85,00,227,,3*7A
16:53:36  $GLGSV,3,3,10,86,28,274,,87,24,339,33,3*7E
16:53:36  $GAGSV,2,1,08,07,28,097,41,11,16,334,36,12,32,279,37,19,47,273,41,7*7A
16:53:36  $GAGSV,2,2,08,20,,,40,27,34,127,46,30,35,061,45,33,16,227,29,7*41
16:53:36  $GAGSV,2,1,07,07,28,097,42,11,16,334,38,12,32,279,39,19,47,273,44,2*76
16:53:36  $GAGSV,2,2,07,27,34,127,45,30,35,061,44,33,16,227,36,2*41
16:53:36  $GBGSV,2,1,07,07,32,071,37,10,,,38,12,,,40,18,,,28,1*48
16:53:36  $GBGSV,2,2,07,19,83,207,49,20,35,120,48,22,34,290,42,1*4B
16:53:36  $GBGSV,1,1,04,07,32,071,,19,83,207,,20,35,120,,22,34,290,,*4E
16:53:36  $GNGLL,5639.83144,N,02340.97291,E,165336.00,A,D*74
16:53:37  $GNRMC,165337.00,A,5639.83144,N,02340.97291,E,0.005,,100919,,,R,V*05
16:53:37  $GNVTG,,T,,M,0.005,N,0.010,K,D*3C
16:53:37  $GNGGA,165337.00,5639.83144,N,02340.97291,E,4,12,0.54,-0.5,M,23.7,M,1.0,0000*43
16:53:37  $GNGSA,A,3,03,07,06,09,23,26,02,16,,,,,1.08,0.54,0.94,1*0F
16:53:37  $GNGSA,A,3,80,79,69,71,87,70,,,,,,,1.08,0.54,0.94,2*00
16:53:37  $GNGSA,A,3,07,12,30,19,33,27,11,,,,,,1.08,0.54,0.94,3*0C
16:53:37  $GNGSA,A,3,19,22,20,07,,,,,,,,,1.08,0.54,0.94,4*0C
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16:53:37  $GPGSV,3,2,10,09,81,241,55,16,24,081,35,23,60,089,49,26,23,050,45,1*67
16:53:37  $GPGSV,3,3,10,29,09,358,40,30,04,206,34,1*69
16:53:37  $GPGSV,3,1,10,02,31,303,,03,22,136,40,06,40,244,33,07,34,192,36,6*6C
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16:53:37  $GPGSV,3,3,10,29,09,358,37,30,04,206,24,6*6F
16:53:37  $GLGSV,3,1,11,69,17,104,47,70,75,079,45,71,46,297,39,72,00,290,,1*73
16:53:37  $GLGSV,3,2,11,73,08,175,33,79,38,042,44,80,52,126,45,85,00,226,24,1*73
16:53:37  $GLGSV,3,3,11,86,28,274,48,87,24,339,46,1*73
16:53:37  $GLGSV,3,1,10,69,17,104,35,70,75,079,,71,46,297,31,72,00,290,,3*7C
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16:53:37  $GAGSV,2,2,07,27,34,127,45,30,35,061,44,33,16,227,37,2*40
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16:53:37  $GBGSV,2,2,07,19,83,207,50,20,35,120,47,22,34,290,42,1*4C
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16:53:38 $GLGSV,3,3,10,86,28,273,,87,24,339,33,3*79
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16:53:38 $GAGSV,2,1,07,07,28,097,42,11,16,334,39,12,32,279,39,19,47,273,44,2*77
16:53:38 $GAGSV,2,2,07,27,34,127,45,30,35,061,44,33,16,227,37,2*40
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16:53:38 $GBGSV,1,1,04,07,32,071,,19,83,207,,20,35,120,,22,34,290,,*4E
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osu cels kaimini sturis.txt
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16:56:28 $GAGSV,3,1,09,02,05,018,,07,27,098,42,11,17,333,32,12,31,278,42,2*78
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16:56:28 $GAGSV,3,3,09,33,15,227,43,2*4B
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16:56:28 $GBGSV,2,1,07,07,32,071,,09,16,082,,10,33,098,,12,17,289,,*41
16:56:28 $GBGSV,2,2,07,19,83,197,,20,34,121,,22,35,290,,*76
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16:56:29 $GPGSV,3,3,10,29,09,357,35,30,06,206,31,1*63
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16:56:29 $GAGSV,3,3,10,30,35,060,39,33,15,227,39,7*72
16:56:29 $GAGSV,3,1,09,02,05,018,,07,27,098,42,11,17,333,32,12,31,278,42,2*78
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16:56:29 $GAGSV,3,3,09,33,15,227,43,2*4B
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16:56:29 $GBGSV,2,2,07,19,83,197,,20,34,121,,22,35,290,,*76
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16:56:30 $GNGSA,A,3,19,09,20,22,12,10,07,,,,,,1.05,0.53,0.90,4*09
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16:56:30 $GPGSV,3,1,10,02,32,302,,03,21,136,40,06,39,243,40,07,35,192,39,6*6E
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16:56:30 $GAGSV,3,2,10,19,48,273,43,20,,,40,21,05,168,,27,35,126,45,7*4E
16:56:30 $GAGSV,3,3,10,30,35,060,40,33,15,227,39,7*7C
16:56:30 $GAGSV,3,1,09,02,05,018,,07,27,098,42,11,17,333,32,12,31,278,42,2*78
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16:56:30 $GAGSV,3,3,09,33,15,227,43,2*4B
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16:56:30 $GNGLL,5639.81365,N,02341.01201,E,165630.00,A,D*73
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17:01:35 $GNGSA,A,3,07,12,30,19,33,27,11,,,,,,0.93,0.48,0.80,3*07
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17:01:35 $GPGSV,3,2,12,07,37,192,43,09,84,232,46,16,26,077,,22,00,136,,6*6C
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17:01:35 $GAGSV,3,1,09,02,04,017,,07,26,099,43,11,18,332,33,12,30,276,43,2*76
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17:01:35 $GAGSV,3,3,09,33,14,226,40,2*48
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17:01:35 $GBGSV,2,1,07,07,33,070,,09,15,083,,10,34,097,,12,16,288,,*4B

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17:01:35 DEBUG: LOCKDET chn 48 (595774), sv G08, reason XCORR (loop 7)
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kaimini talakais sturis.txt
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GPS RTK eksperimenta testu žurnālfailu saturs

osu ozolu krustojums.txt

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07:42:13  $GNGSA,A,3,10,16,15,20,21,27,07,13,26,,,,0.97,0.51,0.83,1*07
07:42:13  $GNGSA,A,3,73,84,83,75,67,66,82,,,,,,0.97,0.51,0.83,2*09
07:42:13  $GNGSA,A,3,03,13,21,01,15,05,,,,,,,0.97,0.51,0.83,3*00
07:42:13  $GNGSA,A,3,12,22,23,25,09,16,,,,,,,0.97,0.51,0.83,4*0E
07:42:13  $GPGSV,3,1,11,04,,,48,07,12,318,37,10,42,175,46,13,15,033,29,1*5F
07:42:13  $GPGSV,3,2,11,15,23,068,40,16,45,219,42,20,62,137,47,21,56,084,47,1*6F
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07:42:13  $GPGSV,3,3,11,26,23,198,,27,61,286,48,30,08,348,36,1*52
07:42:13  $GPGSV,3,1,10,07,12,318,32,10,42,175,43,13,15,033,,15,23,068,35,6*67
07:42:13  $GPGSV,3,2,10,16,45,219,,20,62,137,,21,56,084,,26,23,198,32,6*64
07:42:13  $GPGSV,3,3,10,27,61,286,41,30,08,348,34,6*6A
07:42:13  $GLGSV,2,1,08,66,12,017,38,67,46,064,48,73,20,241,09,75,17,346,38,1*76
07:42:13  $GLGSV,2,2,08,82,26,093,41,83,74,053,38,84,37,289,33,1*4F
07:42:13  $GLGSV,2,1,07,66,12,017,39,67,46,064,41,73,20,241,36,75,17,346,40,3*70
07:42:13  $GLGSV,2,2,07,82,26,093,39,83,74,053,41,84,37,289,42,3*45
07:42:13  $GAGSV,2,1,07,01,13,336,33,03,26,127,39,05,32,068,44,13,38,270,38,7*76
07:42:13  $GAGSV,2,2,07,15,86,090,48,21,36,286,41,27,,,41,7*74
07:42:13  $GAGSV,2,1,06,01,13,336,39,03,26,127,46,05,32,068,42,13,38,270,43,2*7A
07:42:13  $GAGSV,2,2,06,15,86,090,48,21,36,286,44,2*75
07:42:13  $GBGSV,2,1,07,09,21,103,32,12,86,153,46,16,28,086,40,20,05,027,29,1*7D
07:42:13  $GBGSV,2,2,07,22,42,141,47,23,12,338,37,25,20,288,43,1*4E
07:42:13  $GBGSV,2,1,07,09,21,103,,12,86,153,,16,28,086,,20,05,027,,*40
07:42:13  $GBGSV,2,2,07,22,42,141,,23,12,338,,25,20,288,,*7F
07:42:13  $GNGLL,5639.83007,N,02340.97243,E,074213.00,A,D*7A
07:42:14  $GNRMC,074214.00,A,5639.83007,N,02340.97243,E,0.007,,200919,,,R,V*0C
07:42:14  $GNVTG,,T,,M,0.007,N,0.013,K,D*3D
07:42:14  $GNGGA,074214.00,5639.83007,N,02340.97243,E,4,12,0.51,-20.2,M,23.7,M,1.0,0000*7B
07:42:14  $GNGSA,A,3,10,16,15,20,21,27,07,13,26,,,,0.97,0.51,0.83,1*07
07:42:14  $GNGSA,A,3,73,84,83,75,67,66,82,,,,,,0.97,0.51,0.83,2*09
07:42:14  $GNGSA,A,3,03,13,21,01,15,05,,,,,,,0.97,0.51,0.83,3*00
07:42:14  $GNGSA,A,3,12,22,23,25,09,16,,,,,,,0.97,0.51,0.83,4*0E
07:42:14  $GPGSV,3,1,11,04,,,49,07,12,318,39,10,42,175,46,13,15,033,28,1*51
07:42:14  $GPGSV,3,2,11,15,23,068,39,16,45,219,43,20,62,137,46,21,56,084,47,1*61
07:42:14  $GPGSV,3,3,11,26,23,198,,27,61,286,48,30,08,348,36,1*52
07:42:14  $GPGSV,3,1,10,07,12,318,32,10,42,175,43,13,15,033,,15,23,068,35,6*67
07:42:14  $GPGSV,3,2,10,16,45,219,,20,62,137,,21,56,084,,26,23,198,31,6*67
07:42:14  $GPGSV,3,3,10,27,61,286,40,30,08,348,35,6*6A
07:42:14  $GLGSV,2,1,08,66,12,017,38,67,46,064,48,73,20,241,15,75,17,346,40,1*74
07:42:14  $GLGSV,2,2,08,82,26,093,42,83,74,053,39,84,37,289,33,1*4D
07:42:14  $GLGSV,2,1,07,66,12,017,40,67,46,064,42,73,20,241,36,75,17,346,40,3*7D
07:42:14  $GLGSV,2,2,07,82,26,093,39,83,74,053,41,84,37,289,42,3*45
07:42:14  $GAGSV,2,1,07,01,13,336,34,03,26,127,42,05,32,068,45,13,38,270,39,7*7D
07:42:14  $GAGSV,2,2,07,15,86,090,49,21,36,286,42,27,,,41,7*76
07:42:14  $GAGSV,2,1,06,01,13,336,39,03,26,127,46,05,32,068,42,13,38,270,43,2*7A
07:42:14  $GAGSV,2,2,06,15,86,090,48,21,36,286,44,2*75
07:42:14  $GBGSV,2,1,07,09,21,103,32,12,86,153,46,16,28,086,40,20,05,027,29,1*7D
07:42:14  $GBGSV,2,2,07,22,42,141,48,23,12,338,37,25,20,288,43,1*41
07:42:14  $GBGSV,2,1,07,09,21,103,,12,86,153,,16,28,086,,20,05,027,,*40
07:42:14  $GBGSV,2,2,07,22,42,141,,23,12,338,,25,20,288,,*7F
07:42:14  $GNGLL,5639.83007,N,02340.97243,E,074214.00,A,D*7D
07:42:15  $GNRMC,074215.00,A,5639.83007,N,02340.97242,E,0.006,,200919,,,R,V*0D
07:42:15  $GNVTG,,T,,M,0.006,N,0.012,K,D*3D
07:42:15  $GNGGA,074215.00,5639.83007,N,02340.97242,E,4,12,0.51,-20.2,M,23.7,M,1.0,0000*7B
07:42:15  $GNGSA,A,3,10,16,15,20,21,27,07,13,26,,,,0.97,0.51,0.83,1*07
07:42:15  $GNGSA,A,3,73,84,83,75,67,66,82,,,,,,0.97,0.51,0.83,2*09
07:42:15  $GNGSA,A,3,03,13,21,01,15,05,,,,,,,0.97,0.51,0.83,3*00
07:42:15  $GNGSA,A,3,12,22,23,25,09,16,,,,,,,0.97,0.51,0.83,4*0E
07:42:15  $GPGSV,3,1,11,04,,,49,07,12,318,39,10,42,175,46,13,15,033,27,1*5E
07:42:15  $GPGSV,3,2,11,15,23,068,41,16,45,219,43,20,62,137,46,21,56,084,47,1*6E
07:42:15  $GPGSV,3,3,11,26,23,198,,27,61,286,48,30,08,348,36,1*52
07:42:15  $GPGSV,3,1,10,07,12,318,31,10,42,175,43,13,15,033,,15,23,068,35,6*64
07:42:15  $GPGSV,3,2,10,16,45,219,,20,62,137,,21,56,084,,26,23,198,31,6*67
07:42:15  $GPGSV,3,3,10,27,61,286,40,30,08,348,34,6*6B
07:42:15  $GLGSV,2,1,08,66,12,017,39,67,46,064,48,73,20,241,17,75,17,346,40,1*77
07:42:15  $GLGSV,2,2,08,82,26,093,43,83,74,053,39,84,37,289,33,1*4C
07:42:15  $GLGSV,2,1,07,66,12,017,40,67,46,064,42,73,20,241,36,75,17,346,40,3*7D
07:42:15  $GLGSV,2,2,07,82,26,093,40,83,74,053,41,84,37,289,42,3*4B
07:42:15  $GAGSV,2,1,07,01,13,336,33,03,26,127,41,05,32,068,45,13,38,270,38,7*78
07:42:15  $GAGSV,2,2,07,15,86,090,48,21,36,286,41,27,,,40,7*75
07:42:15  $GAGSV,2,1,06,01,13,336,39,03,26,127,46,05,32,068,42,13,38,270,43,2*7A
07:42:15  $GAGSV,2,2,06,15,86,090,48,21,36,286,44,2*75
07:42:15  $GBGSV,2,1,07,09,21,103,33,12,86,153,45,16,28,086,40,20,05,027,29,1*7F
07:42:15  $GBGSV,2,2,07,22,42,141,47,23,12,338,37,25,20,288,43,1*4E
07:42:15  $GBGSV,2,1,07,09,21,103,,12,86,153,,16,28,086,,20,05,027,,*40
07:42:15  $GBGSV,2,2,07,22,42,141,,23,12,338,,25,20,288,,*7F
07:42:15  $GNGLL,5639.83007,N,02340.97242,E,074215.00,A,D*7D
07:42:15  DEBUG: LOCKDET chn 49 (86418), sv Q06, reason XCORR (loop 7)
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07:42:16 $GNRMC,074216.00,A,5639.83007,N,02340.97242,E,0.005,,200919,,,R,V*0D
07:42:16 $GNVTG,,T,,M,0.005,N,0.009,K,D*34
07:42:16 $GNGGA,074216.00,5639.83007,N,02340.97242,E,4,12,0.51,-20.2,M,23.7,M,1.0,0000*78
07:42:16 $GNGSA,A,3,10,16,15,20,21,27,07,13,26,,,,0.97,0.51,0.83,1*07
07:42:16 $GNGSA,A,3,73,84,83,75,67,66,82,,,,,,0.97,0.51,0.83,2*09
07:42:16 $GNGSA,A,3,03,13,21,01,15,05,,,,,,,0.97,0.51,0.83,3*00
07:42:16 $GNGSA,A,3,12,22,23,25,09,16,,,,,,,0.97,0.51,0.83,4*0E
07:42:16 $GPGSV,3,1,11,04,,,49,07,12,318,38,10,42,175,46,13,15,033,27,1*5F
07:42:16 $GPGSV,3,2,11,15,23,068,40,16,45,219,43,20,62,137,46,21,56,084,47,1*6F
07:42:16 $GPGSV,3,3,11,26,23,198,,27,61,286,48,30,08,348,35,1*51
07:42:16 $GPGSV,3,1,10,07,12,318,31,10,42,175,43,13,15,033,,15,23,068,35,6*64
07:42:16 $GPGSV,3,2,10,16,45,219,,20,62,137,,21,56,084,,26,23,198,31,6*67
07:42:16 $GPGSV,3,3,10,27,61,286,40,30,08,348,34,6*6B
07:42:16 DEBUG: LOCKDET chn 41 (87118), sv Q06, reason XCORR (loop 7)
07:42:16 $GLGSV,2,1,08,66,12,017,40,67,46,064,48,73,20,241,16,75,17,346,40,1*78
07:42:16 $GLGSV,2,2,08,82,26,093,43,83,74,053,39,84,37,289,33,1*4C
07:42:16 $GLGSV,2,1,07,66,12,017,40,67,46,064,42,73,20,241,36,75,17,346,40,3*7D
07:42:16 $GLGSV,2,2,07,82,26,093,40,83,74,053,40,84,37,289,43,3*4B
07:42:16 $GAGSV,2,1,07,01,13,336,34,03,26,127,41,05,32,068,45,13,38,270,39,7*7E
07:42:16 $GAGSV,2,2,07,15,86,090,48,21,36,286,41,27,,,41,7*74
07:42:16 $GAGSV,2,1,06,01,13,336,39,03,26,127,46,05,32,068,42,13,38,270,44,2*7D
07:42:16 $GAGSV,2,2,06,15,86,090,48,21,36,286,44,2*75
07:42:16 $GBGSV,2,1,08,09,21,103,34,12,86,153,46,16,28,086,40,18,,,36,1*41
07:42:16 $GBGSV,2,2,08,20,05,027,28,22,42,141,47,23,12,338,37,25,20,288,43,1*79
07:42:16 $GBGSV,2,1,07,09,21,103,,12,86,153,,16,28,086,,20,05,027,,*40
07:42:16 $GBGSV,2,2,07,22,42,141,,23,12,338,,25,20,288,,*7F
07:42:16 $GNGLL,5639.83007,N,02340.97242,E,074216.00,A,D*7E
07:42:17 $GNRMC,074217.00,A,5639.83007,N,02340.97243,E,0.005,,200919,,,R,V*0D
07:42:17 $GNVTG,,T,,M,0.005,N,0.009,K,D*34
07:42:17 $GNGGA,074217.00,5639.83007,N,02340.97243,E,4,12,0.51,-20.2,M,23.7,M,1.0,0000*78
07:42:17 $GNGSA,A,3,10,16,15,20,21,27,07,13,26,,,,0.97,0.51,0.83,1*07
07:42:17 $GNGSA,A,3,73,84,83,75,67,66,82,,,,,,0.97,0.51,0.83,2*09
07:42:17 $GNGSA,A,3,03,13,21,01,15,05,,,,,,,0.97,0.51,0.83,3*00
07:42:17 $GNGSA,A,3,12,22,23,25,09,16,,,,,,,0.97,0.51,0.83,4*0E
07:42:17 $GPGSV,3,1,11,04,,,48,07,12,318,38,10,42,175,46,13,15,033,27,1*5E
07:42:17 $GPGSV,3,2,11,15,23,068,39,16,45,219,43,20,62,137,46,21,56,084,47,1*61
07:42:17 $GPGSV,3,3,11,26,23,198,,27,61,286,48,30,08,348,34,1*50
07:42:17 $GPGSV,3,1,10,07,12,318,31,10,42,175,43,13,15,033,,15,23,068,35,6*64
07:42:17 $GPGSV,3,2,10,16,45,219,,20,62,137,,21,56,084,,26,23,198,31,6*67
07:42:17 $GPGSV,3,3,10,27,61,286,41,30,08,348,34,6*6A
07:42:17 $GLGSV,2,1,08,66,12,017,40,67,46,064,48,73,20,241,15,75,17,346,40,1*7B
07:42:17 $GLGSV,2,2,08,82,26,093,43,83,74,053,39,84,37,289,32,1*4D
07:42:17 $GLGSV,2,1,07,66,12,017,40,67,46,064,42,73,20,241,36,75,17,346,39,3*73
07:42:17 $GLGSV,2,2,07,82,26,093,40,83,74,053,41,84,37,289,43,3*4A
07:42:17 $GAGSV,2,1,07,01,13,336,34,03,26,127,41,05,32,068,45,13,38,270,38,7*7F
07:42:17 $GAGSV,2,2,07,15,86,090,48,21,36,286,41,27,,,41,7*74
07:42:17 $GAGSV,2,1,06,01,13,336,39,03,26,127,46,05,32,068,42,13,38,270,44,2*7D
07:42:17 $GAGSV,2,2,06,15,86,090,48,21,36,286,44,2*75
07:42:17 $GBGSV,2,1,08,09,21,103,34,12,86,153,46,16,28,086,41,18,,,35,1*43
07:42:17 $GBGSV,2,2,08,20,05,027,28,22,42,141,47,23,12,338,37,25,20,288,43,1*79
07:42:17 $GBGSV,2,1,07,09,21,103,,12,86,153,,16,28,086,,20,05,027,,*40
07:42:17 $GBGSV,2,2,07,22,42,141,,23,12,338,,25,20,288,,*7F
07:42:17 $GNGLL,5639.83007,N,02340.97243,E,074217.00,A,D*7E
07:42:17 DEBUG: LOCKDET chn 49 (88546), sv G01, reason XCORR (loop 7)

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07:45:11 $GNRMC,074511.00,A,5639.81233,N,02341.01148,E,0.009,,200919,,,R,V*01
07:45:11 $GNVTG,,T,,M,0.009,N,0.017,K,D*37
07:45:11 $GNGGA,074511.00,5639.81233,N,02341.01148,E,4,12,0.49,-20.5,M,23.7,M,1.0,0000*76
07:45:11 $GNGSA,A,3,10,13,15,20,21,27,07,16,26,08,,,0.94,0.49,0.80,1*06
07:45:11 $GNGSA,A,3,73,84,83,75,67,66,82,,,,,,0.94,0.49,0.80,2*00
07:45:11 $GNGSA,A,3,03,27,13,21,01,15,05,,,,,,0.94,0.49,0.80,3*0C
07:45:11 $GNGSA,A,3,09,12,22,25,16,,,,,,,,0.94,0.49,0.80,4*06
07:45:11 $GPGSV,3,1,12,04,,,47,07,12,317,41,08,24,298,38,10,44,174,47,1*50
07:45:11 $GPGSV,3,2,12,13,15,032,37,15,23,067,46,16,44,218,39,20,62,135,48,1*68
07:45:11 $GPGSV,3,3,12,21,55,084,49,26,22,198,41,27,62,285,51,30,08,347,,1*65
07:45:11 $GPGSV,3,1,11,07,12,317,35,08,24,298,39,10,44,174,44,13,15,032,,6*65
07:45:11 $GPGSV,3,2,11,15,23,067,38,16,44,218,,20,62,135,,21,55,084,,6*6F
07:45:11 $GPGSV,3,3,11,26,22,198,32,27,62,285,44,30,08,347,,6*53
07:45:11 $GLGSV,3,1,11,66,11,017,26,67,46,062,43,68,36,140,,69,00,172,,1*7D

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07:45:11  $GLGSV,3,2,11,73,19,240,35,74,35,286,,75,18,345,45,82,25,094,41,1*71
07:45:11  $GLGSV,3,3,11,83,73,057,39,84,38,290,43,1*74
07:45:11  $GLGSV,3,1,10,66,11,017,14,67,46,062,38,68,36,140,,69,00,172,,3*73
07:45:11  $GLGSV,3,2,10,73,19,240,34,74,35,286,,75,18,345,36,82,25,094,38,3*79
07:45:11  $GLGSV,3,3,10,83,73,057,42,84,38,290,38,3*77
07:45:11  $GAGSV,2,1,08,01,14,336,35,03,27,126,44,05,32,066,40,09,08,020,,7*7C
07:45:11  $GAGSV,2,2,08,13,39,270,45,15,85,090,48,21,36,284,46,27,24,225,38,7*7C
07:45:11  $GAGSV,2,1,08,01,14,336,36,03,27,126,46,05,32,066,40,09,08,020,,2*78
07:45:11  $GAGSV,2,2,08,13,39,270,44,15,85,090,48,21,36,284,45,27,24,225,39,2*7A
07:45:11  $GBGSV,2,1,08,06,,,39,09,22,103,36,12,85,144,46,16,28,085,38,1*49
07:45:11  $GBGSV,2,2,08,20,04,027,,22,44,140,46,23,13,337,,25,20,287,34,1*71
07:45:11  $GBGSV,2,1,07,09,22,103,,12,85,144,,16,28,085,,20,04,027,,*44
07:45:11  $GBGSV,2,2,07,22,44,140,,23,13,337,,25,20,287,,*79
07:45:11  $GNGLL,5639.81233,N,02341.01148,E,074511.00,A,D*7E
07:45:12  $GNRMC,074512.00,A,5639.81233,N,02341.01147,E,0.004,,200919,,,R,V*00
07:45:12  $GNVTG,,T,,M,0.004,N,0.007,K,D*3B
07:45:12  $GNGGA,074512.00,5639.81233,N,02341.01147,E,4,12,0.49,-20.5,M,23.7,M,1.0,0000*7A
07:45:12  $GNGSA,A,3,10,13,15,20,21,27,07,16,26,08,,,0.94,0.49,0.80,1*06
07:45:12  $GNGSA,A,3,73,84,83,75,67,66,82,,,,,,0.94,0.49,0.80,2*00
07:45:12  $GNGSA,A,3,03,27,13,21,01,15,05,,,,,,0.94,0.49,0.80,3*0C
07:45:12  $GNGSA,A,3,09,12,22,25,16,,,,,,,,0.94,0.49,0.80,4*06
07:45:12  $GPGSV,3,1,12,04,,,47,07,12,317,41,08,24,298,38,10,44,174,47,1*50
07:45:12  $GPGSV,3,2,12,13,15,032,37,15,23,067,46,16,44,218,39,20,62,135,48,1*68
07:45:12  $GPGSV,3,3,12,21,55,084,49,26,22,198,41,27,62,285,51,30,08,347,,1*65
07:45:12  $GPGSV,3,1,11,07,12,317,35,08,24,298,39,10,44,174,44,13,15,032,,6*65
07:45:12  $GPGSV,3,2,11,15,23,067,38,16,44,218,,20,62,135,,21,55,084,,6*6F
07:45:12  $GPGSV,3,3,11,26,22,198,32,27,62,285,44,30,08,347,,6*53
07:45:12  $GLGSV,3,1,11,66,11,017,27,67,46,062,43,68,36,140,,69,00,172,,1*7C
07:45:12  $GLGSV,3,2,11,73,19,240,35,74,35,286,,75,18,345,45,82,25,094,41,1*71
07:45:12  $GLGSV,3,3,11,83,73,057,39,84,38,290,43,1*74
07:45:12  $GLGSV,3,1,10,66,11,017,13,67,46,062,38,68,36,140,,69,00,172,,3*74
07:45:12  $GLGSV,3,2,10,73,19,240,34,74,35,286,,75,18,345,36,82,25,094,38,3*79
07:45:12  $GLGSV,3,3,10,83,73,057,42,84,38,290,38,3*77
07:45:12  $GAGSV,2,1,08,01,14,336,35,03,27,126,43,05,32,066,39,09,08,020,,7*75
07:45:12  $GAGSV,2,2,08,13,39,270,45,15,85,090,47,21,36,284,45,27,24,225,37,7*7F
07:45:12  $GAGSV,2,1,08,01,14,336,37,03,27,126,46,05,32,066,40,09,08,020,,2*79
07:45:12  $GAGSV,2,2,08,13,39,270,44,15,85,090,48,21,36,284,45,27,24,225,38,2*7B
07:45:12  $GBGSV,2,1,08,06,,,39,09,22,103,36,12,85,144,46,16,28,085,37,1*46
07:45:12  $GBGSV,2,2,08,20,04,027,,22,44,140,46,23,13,337,,25,20,287,33,1*76
07:45:12  $GBGSV,2,1,07,09,22,103,,12,85,144,,16,28,085,,20,04,027,,*44
07:45:12  $GBGSV,2,2,07,22,44,140,,23,13,337,,25,20,287,,*79
07:45:12  $GNGLL,5639.81233,N,02341.01147,E,074512.00,A,D*72
07:45:13  $GNRMC,074513.00,A,5639.81233,N,02341.01148,E,0.012,,200919,,,R,V*09
07:45:13  $GNVTG,,T,,M,0.012,N,0.023,K,D*3A
07:45:13  $GNGGA,074513.00,5639.81233,N,02341.01148,E,4,12,0.49,-20.5,M,23.7,M,1.0,0000*74
07:45:13  $GNGSA,A,3,10,13,15,20,21,27,07,16,26,08,,,0.94,0.49,0.80,1*06
07:45:13  $GNGSA,A,3,73,84,83,75,67,66,82,,,,,,0.94,0.49,0.80,2*00
07:45:13  $GNGSA,A,3,03,27,13,21,01,15,05,,,,,,0.94,0.49,0.80,3*0C
07:45:13  $GNGSA,A,3,09,12,22,25,16,,,,,,,,0.94,0.49,0.80,4*06
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07:45:13  $GPGSV,3,3,12,21,55,084,49,26,22,198,41,27,62,285,51,30,08,347,,1*65
07:45:13  $GPGSV,3,1,11,07,12,317,35,08,24,298,39,10,44,174,43,13,15,032,,6*62
07:45:13  $GPGSV,3,2,11,15,23,067,38,16,44,218,,20,62,135,,21,55,084,,6*6F
07:45:13  $GPGSV,3,3,11,26,22,198,32,27,62,285,44,30,08,347,,6*53
07:45:13  $GLGSV,3,1,11,66,11,016,27,67,46,062,43,68,36,140,,69,00,172,,1*7D
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07:45:13  $GLGSV,3,3,11,83,73,057,39,84,38,290,43,1*74
07:45:13  $GLGSV,3,1,10,66,11,016,13,67,46,062,38,68,36,140,,69,00,172,,3*75
07:45:13  $GLGSV,3,2,10,73,19,240,33,74,35,286,,75,18,345,36,82,25,094,38,3*7E
07:45:13  $GLGSV,3,3,10,83,73,057,42,84,38,290,38,3*77
07:45:13  $GAGSV,2,1,08,01,14,336,35,03,27,126,44,05,32,066,40,09,08,020,,7*7C
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07:45:13  $GAGSV,2,1,08,01,14,336,37,03,27,126,46,05,32,066,40,09,08,020,,2*79
07:45:13  $GAGSV,2,2,08,13,39,270,44,15,85,090,48,21,36,284,45,27,24,225,38,2*7B
07:45:13  $GBGSV,2,1,08,06,,,39,09,22,103,36,12,85,144,46,16,28,085,37,1*46
07:45:13  $GBGSV,2,2,08,20,04,027,,22,44,140,46,23,13,337,,25,20,287,33,1*76
07:45:13  $GBGSV,2,1,07,09,22,103,,12,85,144,,16,28,085,,20,04,027,,*44
07:45:13  $GBGSV,2,2,07,22,44,140,,23,13,337,,25,20,287,,*79
07:45:13  $GNGLL,5639.81233,N,02341.01148,E,074513.00,A,D*7C
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07:49:02 $GNRMC,074902.00,A,5639.85838,N,02341.02436,E,0.016,,200919,,,R,V*0B
07:49:02 $GNVTG,,T,,M,0.016,N,0.029,K,D*34
07:49:02 $GNGGA,074902.00,5639.85838,N,02341.02436,E,4,12,0.49,-20.0,M,23.7,M,1.0,0000*77
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07:49:02 $GNGSA,A,3,73,84,83,75,67,82,,,,,,,0.92,0.49,0.78,2*01
07:49:02 $GNGSA,A,3,03,27,13,21,01,15,05,,,,,,0.92,0.49,0.78,3*0D
07:49:02 $GNGSA,A,3,09,12,22,25,13,16,06,,,,,,0.92,0.49,0.78,4*03
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07:49:02 $GPGSV,3,2,12,13,15,030,38,15,24,065,42,16,42,217,46,20,63,131,47,1*6F
07:49:02 $GPGSV,3,3,12,21,54,084,49,26,20,197,41,27,64,284,49,30,08,346,40,1*62
07:49:02 $GPGSV,3,1,11,07,11,316,33,08,25,298,42,10,46,173,44,13,15,030,,6*6B
07:49:02 $GPGSV,3,2,11,15,24,065,37,16,42,217,,20,63,131,,21,54,084,,6*68
07:49:02 $GPGSV,3,3,11,26,20,197,35,27,64,284,45,30,08,346,,6*5E
07:49:02 $GLGSV,3,1,11,66,10,016,38,67,46,059,47,68,38,139,,69,02,171,,1*7F
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07:49:02 $GLGSV,3,3,11,83,72,063,40,84,40,292,45,1*77
07:49:02 $GLGSV,3,1,10,66,10,016,29,67,46,059,40,68,38,139,,69,02,171,,3*7B
07:49:02 $GLGSV,3,2,10,73,17,239,30,74,34,284,,75,19,344,38,82,24,096,35,3*7E
07:49:02 $GLGSV,3,3,10,83,72,063,41,84,40,292,41,3*71
07:49:02 $GAGSV,2,1,08,01,15,335,39,03,28,126,35,05,32,065,41,09,08,019,,7*73
07:49:02 $GAGSV,2,2,08,13,40,271,45,15,84,091,48,21,36,283,46,27,22,225,44,7*79
07:49:02 $GAGSV,2,1,08,01,15,335,37,03,28,126,40,05,32,065,45,09,08,019,,2*7E
07:49:02 $GAGSV,2,2,08,13,40,271,42,15,84,091,47,21,36,283,45,27,22,225,42,2*71
07:49:02 $GBGSV,3,1,09,06,29,076,41,09,23,103,34,12,84,140,45,13,16,079,31,1*7B
07:49:02 $GBGSV,3,2,09,16,29,085,43,20,03,027,,22,45,139,48,23,13,336,,1*7F
07:49:02 $GBGSV,3,3,09,25,19,286,38,1*47
07:49:02 $GBGSV,3,1,09,06,29,076,,09,23,103,,12,84,140,,13,16,079,,*4B
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07:49:02 $GBGSV,3,3,09,25,19,286,,*7D
07:49:02 $GNGLL,5639.85838,N,02341.02436,E,074902.00,A,D*7A
07:49:03 $GNRMC,074903.00,A,5639.85838,N,02341.02436,E,0.017,,200919,,,R,V*0B
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07:49:03 $GNGSA,A,3,10,13,15,20,21,27,07,16,26,08,,,0.92,0.49,0.78,1*07
07:49:03 $GNGSA,A,3,73,84,83,75,67,82,,,,,,,0.92,0.49,0.78,2*01
07:49:03 $GNGSA,A,3,03,27,13,21,01,15,05,,,,,,0.92,0.49,0.78,3*0D
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07:49:03 $GPGSV,3,2,12,13,15,030,39,15,24,065,42,16,42,217,46,20,63,131,47,1*6E
07:49:03 $GPGSV,3,3,12,21,54,084,49,26,20,197,41,27,64,284,49,30,08,346,40,1*62
07:49:03 $GPGSV,3,1,11,07,11,316,33,08,25,298,42,10,46,173,44,13,15,030,,6*6B
07:49:03 $GPGSV,3,2,11,15,24,065,37,16,42,217,,20,63,131,,21,54,084,,6*68
07:49:03 $GPGSV,3,3,11,26,20,197,35,27,64,284,45,30,08,346,,6*5E
07:49:03 $GLGSV,3,1,11,66,10,016,39,67,46,059,47,68,38,139,,69,02,171,,1*7E
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07:49:03 $GLGSV,3,3,11,83,72,063,40,84,40,292,45,1*77
07:49:03 $GLGSV,3,1,10,66,10,016,29,67,46,059,40,68,38,139,,69,02,171,,3*7B
07:49:03 $GLGSV,3,2,10,73,17,239,30,74,34,284,,75,19,344,38,82,24,096,35,3*7E
07:49:03 $GLGSV,3,3,10,83,72,063,41,84,40,292,40,3*70
07:49:03 $GAGSV,2,1,08,01,15,335,38,03,28,126,35,05,32,065,41,09,08,019,,7*72
07:49:03 $GAGSV,2,2,08,13,40,271,45,15,84,091,47,21,36,283,45,27,22,225,44,7*75
07:49:03 $GAGSV,2,1,08,01,15,335,37,03,28,126,40,05,32,065,45,09,08,019,,2*7E
07:49:03 $GAGSV,2,2,08,13,40,271,42,15,84,091,47,21,36,283,45,27,22,225,42,2*71
07:49:03 $GBGSV,3,1,09,06,29,076,41,09,23,103,34,12,84,140,45,13,16,079,31,1*7B
07:49:03 $GBGSV,3,2,09,16,29,085,43,20,03,027,,22,45,139,47,23,13,336,,1*70
07:49:03 $GBGSV,3,3,09,25,19,286,38,1*47
07:49:03 $GBGSV,3,1,09,06,29,076,,09,23,103,,12,84,140,,13,16,079,,*4B
07:49:03 $GBGSV,3,2,09,16,29,085,,20,03,027,,22,45,139,,23,13,336,,*45
07:49:03 $GBGSV,3,3,09,25,19,286,,*7D
07:49:03 $GNGLL,5639.85838,N,02341.02436,E,074903.00,A,D*7B
07:49:03 DEBUG: LOCKDET chn 50 (494458), sv Q10, reason XCORR (loop 7)
07:49:04 $GNRMC,074904.00,A,5639.85838,N,02341.02436,E,0.009,,200919,,,R,V*03
07:49:04 $GNVTG,,T,,M,0.009,N,0.017,K,D*37
07:49:04 $GNGGA,074904.00,5639.85838,N,02341.02436,E,4,12,0.49,-20.0,M,23.7,M,1.0,0000*71
07:49:04 $GNGSA,A,3,10,13,15,20,21,27,07,16,26,08,,,0.92,0.49,0.78,1*07
07:49:04 $GNGSA,A,3,73,84,83,75,67,82,,,,,,,0.92,0.49,0.78,2*01
07:49:04 $GNGSA,A,3,03,27,13,21,01,15,05,,,,,,0.92,0.49,0.78,3*0D
07:49:04 $GNGSA,A,3,09,12,22,25,13,16,06,,,,,,0.92,0.49,0.78,4*03

07:49:04 $GPGSV,3,1,12,04,,,48,07,11,316,39,08,25,298,42,10,46,173,48,1*54
07:49:04 $GPGSV,3,2,12,13,15,030,39,15,24,065,42,16,42,217,46,20,63,131,47,1*6E
07:49:04 $GPGSV,3,3,12,21,54,084,49,26,20,197,41,27,64,284,49,30,08,346,40,1*62
07:49:04 $GPGSV,3,1,11,07,11,316,33,08,25,298,42,10,46,173,44,13,15,030,,6*6B
07:49:04 $GPGSV,3,2,11,15,24,065,36,16,42,217,,20,63,131,,21,54,084,,6*69
07:49:04 $GPGSV,3,3,11,26,20,197,36,27,64,284,46,30,08,346,,6*5E
07:49:04 $GLGSV,3,1,11,66,10,016,38,67,46,059,47,68,38,139,,69,02,171,,1*7F
07:49:04 $GLGSV,3,2,11,73,17,239,36,74,34,284,,75,19,344,47,82,24,096,44,1*75
07:49:04 $GLGSV,3,3,11,83,72,063,40,84,40,292,45,1*77
07:49:04 $GLGSV,3,1,10,66,10,016,29,67,46,059,40,68,38,139,,69,02,171,,3*7B
07:49:04 $GLGSV,3,2,10,73,17,239,29,74,34,284,,75,19,344,38,82,24,096,35,3*76
07:49:04 $GLGSV,3,3,10,83,72,063,41,84,40,292,40,3*70
07:49:04 $GAGSV,2,1,08,01,15,335,38,03,28,126,34,05,32,065,41,09,08,019,,7*73
07:49:04 $GAGSV,2,2,08,13,40,271,44,15,84,091,47,21,36,283,45,27,22,225,44,7*74
07:49:04 $GAGSV,2,1,08,01,15,335,37,03,28,126,40,05,32,065,45,09,08,019,,2*7E
07:49:04 $GAGSV,2,2,08,13,40,271,42,15,84,091,47,21,36,283,45,27,22,225,42,2*71
07:49:04 $GBGSV,3,1,09,06,29,076,41,09,23,103,34,12,84,138,45,13,16,079,31,1*74
07:49:04 $GBGSV,3,2,09,16,29,085,43,20,03,027,,22,45,139,47,23,13,336,,1*70
07:49:04 $GBGSV,3,3,09,25,19,286,38,1*47
07:49:04 $GBGSV,3,1,09,06,29,076,,09,23,103,,12,84,138,,13,16,079,,*44
07:49:04 $GBGSV,3,2,09,16,29,085,,20,03,027,,22,45,139,,23,13,336,,*45
07:49:04 $GBGSV,3,3,09,25,19,286,,*7D
07:49:04 $GNGLL,5639.85838,N,02341.02436,E,074904.00,A,D*7C

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07:51:05 $GNRMC,075105.00,A,5639.84201,N,02341.05937,E,0.012,,200919,,,R,V*0B
07:51:05 $GNVTG,,T,,M,0.012,N,0.022,K,D*3B
07:51:05 $GNGGA,075105.00,5639.84201,N,02341.05937,E,4,12,0.50,-20.6,M,23.7,M,1.0,0000*7D
07:51:05 $GNGSA,A,3,10,13,15,20,21,27,07,16,26,08,,,0.95,0.50,0.81,1*0E
07:51:05 $GNGSA,A,3,73,84,83,75,67,82,,,,,,,0.95,0.50,0.81,2*08
07:51:05 $GNGSA,A,3,03,27,13,21,01,15,05,,,,,,0.95,0.50,0.81,3*04
07:51:05 $GNGSA,A,3,09,12,22,25,16,06,,,,,,,0.95,0.50,0.81,4*08
07:51:05 $GPGSV,3,1,12,04,,,47,07,11,315,34,08,26,298,40,10,46,173,49,1*55
07:51:05 $GPGSV,3,2,12,13,15,030,33,15,24,065,48,16,41,216,44,20,63,130,48,1*60
07:51:05 $GPGSV,3,3,12,21,53,084,48,26,20,197,33,27,64,283,50,30,08,345,,1*69
07:51:05 $GPGSV,3,1,11,07,11,315,25,08,26,298,38,10,46,173,45,13,15,030,,6*60
07:51:05 $GPGSV,3,2,11,15,24,065,34,16,41,216,,20,63,130,,21,53,084,,6*6F
07:51:05 $GPGSV,3,3,11,26,20,197,27,27,64,283,47,30,08,345,27,6*5E
07:51:05 $GLGSV,3,1,11,66,09,016,28,67,45,057,48,68,39,138,,69,03,171,,1*75
07:51:05 $GLGSV,3,2,11,73,16,238,26,74,33,282,,75,20,343,44,82,22,097,41,1*79
07:51:05 $GLGSV,3,3,11,83,71,066,38,84,41,293,44,1*7F
07:51:05 $GLGSV,3,1,10,66,09,016,23,67,45,057,42,68,39,138,,69,03,171,,3*77
07:51:05 $GLGSV,3,2,10,73,16,238,25,74,33,282,,75,20,343,36,82,22,097,39,3*73
07:51:05 $GLGSV,3,3,10,83,71,066,41,84,41,293,43,3*75
07:51:05 $GAGSV,3,1,09,01,15,335,35,03,28,125,39,05,32,064,46,08,00,167,,7*77
07:51:05 $GAGSV,3,2,09,09,07,019,,13,41,271,42,15,83,092,47,21,35,282,42,7*74
07:51:05 $GAGSV,3,3,09,27,22,224,37,7*4F
07:51:05 $GAGSV,3,1,09,01,15,335,16,03,28,125,41,05,32,064,45,08,00,167,,2*7F
07:51:05 $GAGSV,3,2,09,09,07,019,,13,41,271,44,15,83,092,47,21,35,282,45,2*70
07:51:05 $GAGSV,3,3,09,27,22,224,32,2*4F
07:51:05 $GBGSV,3,1,10,06,29,075,41,09,23,103,30,11,,,41,12,83,136,45,1*4E
07:51:05 $GBGSV,3,2,10,13,15,079,,16,29,085,47,20,02,027,,22,46,138,40,1*75
07:51:05 $GBGSV,3,3,10,23,13,335,,25,19,285,40,1*75
07:51:05 $GBGSV,3,1,09,06,29,075,,09,23,103,,12,83,136,,13,15,079,,*4D
07:51:05 $GBGSV,3,2,09,16,29,085,,20,02,027,,22,46,138,,23,13,335,,*45
07:51:05 $GBGSV,3,3,09,25,19,285,,*7E
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07:51:05 DEBUG: LOCKDET chn 39 (616259), sv Q01, reason XCORR (loop 7)
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12. pielikums

GPS RTK eksperimenta testu žurnālfailu saturs

Atkartojums Nr.1.


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13. pielikums

Eksperimentu stenda datorprogrammas komunikācijas veidošanas kods

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using System;
using System.IO;
using System.Net.Sockets;
using System.Text;
using System.Threading;

namespace UR10
{
    public interface IConnection
    {
        (bool, string) ConnectToUr10();
        (bool, string) DisconnectFromUr10();
        Stream GetStream();
        void SendServiceMessage(string message);
    }

    class Connection: IConnection
    {
        TcpClient client;
        TcpClient clientInitializeRobot;
        Stream serviceStream;

        public (bool, string) ConnectToUr10()
        {
            string exception = null;
            try
            {
                client = new TcpClient();
                client.Connect(Properties.Settings.Default.IpAddress, 30001);

                clientInitializeRobot = new TcpClient();
                clientInitializeRobot.Connect(Properties.Settings.Default.IpAddress, 29999);
                serviceStream = clientInitializeRobot.GetStream();
            }
            catch(Exception exc)
            {
                exception = exc.ToString();
            }

            return (client.Connected && clientInitializeRobot.Connected, exception);
        }

        public (bool, string) DisconnectFromUr10()
        {
            string exception = null;
            try
            {
                client.Close();
                client.Dispose();

                clientInitializeRobot.Close();
                clientInitializeRobot.Dispose();
            }
            catch (Exception exc)
            {
                exception = exc.ToString();
            }

            return (!client.Connected && !clientInitializeRobot.Connected, exception);
        }
```

```
public Stream GetStream()
{
    return client.GetStream();
}

public void SendServiceMessage(string message)
{
    byte[] messageBytes = Encoding.ASCII.GetBytes(message+"\n");
    serviceStream.Write(messageBytes, 0, messageBytes.Length);
    Thread.Sleep(5000);
}
```

14. pielikums

Eksperimentu stenda datorprogrammas fotoattēlu uzņemšanas un organizēšanas kods

```
using System;
using System.Diagnostics;
using System.IO;

namespace UR10
{
    public interface IPhotoCapturer
    {
        (string output, string errors) CapturePhoto();
        string OrganizePhotoFiles(string folderName, int index);
    }

    public class PhotoCapturer : IPhotoCapturer
    {
        private const string workingFolder = "./RealSenseTools/";
        public (string output, string errors) CapturePhoto()
        {
            Process p = new Process();
            p.StartInfo.UseShellExecute = false;
            p.StartInfo.RedirectStandardOutput = true;
            p.StartInfo.RedirectStandardError = true;
            p.StartInfo.FileName = $"{workingFolder}rs-save-to-disk.exe";
            p.Start();
            string output = p.StandardOutput.ReadToEnd();
            string errors = p.StandardError.ReadToEnd();
            p.WaitForExit();

            return (output, errors);
        }

        public string OrganizePhotoFiles(string folderName, int index)
        {
            string folderPath = Path.Combine(workingFolder, folderName);
            //Directory.CreateDirectory(folderPath);

            string colorPhotoPath = "rs-save-to-disk-output-Color.png";
            string depthPhotoPath = "rs-save-to-disk-output-Depth.png";

            if (!File.Exists(colorPhotoPath))
            {
                return $"Error: {colorPhotoPath} doesn't exist";
            }

            if (!File.Exists(colorPhotoPath))
            {
                return $"Error: {depthPhotoPath} doesn't exist";
            }

            string fileName = $"{index}index{DateTime.Now.ToString().Replace(":", "-").Replace("/", "-")}-Color.png";
            File.Move(colorPhotoPath, Path.Combine(Properties.Settings.Default.PhotosFolderPath, "rawscaled", fileName));
            //File.Move(depthPhotoPath, Path.Combine(folderPath, $"{DateTime.Now.ToString().Replace(":", "-").Replace("/", "-")}-
Depth.png"));

            return fileName;
        }
    }
}
```

15. pielikums

R skripts augu zaļās masas noteikšanas RGB rastra attēlā

```
library(raster)
library(icesTAF)
library(SparkR)
convert2GLF <- function(photo_filename)
{
	foto_st <- stack(photo_filename)
	foto_br <- brick(foto_st)

	#Green leaf index
	#https://www.indexdatabase.de/db/i-single.php?id=375
	GLF <- (2 * foto_br[[2]] - foto_br[[1]] - foto_br[[3]]) / (2 * foto_br[[2]] + foto_br[[1]] + foto_br[[3]])
	#Treshold for green
	GLF_TH <- as.integer(GLF[[1]] > 0.16)
	#Filtering noise, using focal function with default sum, becautse it is faster (gf - Gaussian filter object)
	gf <- focalWeight(GLF_TH, 5, "Gauss")
	#focal - filtering function
	GLF_GF <- focal(GLF_TH, w=gf)
	#Removing transitions after Gausian filter
	GLF_GF <- as.integer(GLF_GF[[1]] > 0.8)
	#remove NA values on edges of raster after focal filtering
	GLF_GF[is.na(GLF_GF[])] <- 0

	f <- freq(GLF_GF)[2,][[2]]
	dataf <- data.frame(basename(photo_filename),f)
	mkdir(paste(dirname(photo_filename), "/Processed", sep=""))
	photo_filename <- paste(dirname(photo_filename), "/Processed/", strsplit(basename(photo_filename),'[.]')[[1]][1], "_GLF.png", sep="")
	write.table(dataf, file = paste(dirname(photo_filename), "/data.txt", sep=""), row.names = FALSE, col.names=FALSE, append=TRUE)

	png(filename=photo_filename, width=ncol(GLF_GF), height=nrow(GLF_GF))
	plot(GLF_GF, axes = FALSE, box = FALSE)
	dev.off()
	rm(foto_st)
	rm(foto_br)
	rm(GLF)
	rm(GLF_TH)
	rm(gf)
	rm(GLF_GF)
}
```

Lāzera izmantošana nezāļu ierobežošanā

Jānis Jaško, LLU Augu aizsardzības zinātniskais institūts Agrihorts

Nezāles, kaitēkļi un slimības veido 'lielo trijnieku', kas sagādā galvassāpes lauksaimniekiem jau izsenis. Attīstoties tehnoloģijām, papildinās arī pieejamo rīku klāsts, kā ar nezālēm tikt galā. Piemēram, precīzie rušinātāji, kas ar dažu centimetru precizitāti kultivē rindstarpas laukaugiem, nu jau vairākus gadus ir zemnieku rīcībā. Šogad Agrihorta realizētajā projektā kopā ar ZS Vilciņi-1 šāda veida iekārta tika veiksmīgi izmēģināta lauka pupu sējumā. Tā ka var droši teikt, ka iekārta ar centimetru precizitāti nezāļu ierobežošanā šodien Latvijā vairs nav jaunums, tāpēc zinātniekiem nekas cits neatliek, ka celt precizitātes latiņu vēl augstāk.

Pie tā arī strādā Latvijas Lauksaimniecības universitātes pētnieki, sadarbībā ar Elektronikas un datorzinātņu institūtu un trim bioloģiskajām saimniecībām projektā RONIN "Robotizētas nezāļu ierobežošanas iekārtas izveide" (Projekta Nr. 18-00-A01612-000024). Projekta mērķis ir izstrādāt nezāļu ierobežošanas iekārtu, kas, pielietojot mākslīgā intelekta risinājumus, spēj autonomi pārvietoties pa lauku, identificēt nezāles un atšķirt tās no kultūrauga, kā arī, izmantojot augstas enerģijas lāzera vai precīzi pozicionēta mehāniskā agregāta palīdzību, iznīcināt nezāli vai būtiski traucēt tās turpmāko augšanu. Projektā tiek strādāts vairākos virzienos, kas paši par sevi jau ir atsevišķu projektu cienīgi: augstas precizitātes RTK GPS tehnoloģijas, augu atpazīšana un autonomi lauksaimniecības roboti. Šajā rakstā ieskicēšu galvenās atziņas tieši par precīzo ravēšanu – augu apstrādi ar lāzera starojumu.

Noteikti jāpiemin, ka neesam pirmie, kas izmanto lāzera enerģiju, lai ierobežotu nezāles. Pirmās lāzeru ravēšanas iekārtas patentētas jau deviņdesmito gadu sākumā. Ar ieviešanu praksē gan tik raiti nav gājis, un vismaz pagaidām man nav izdevies atrast zemniekam nopērkamu lāzerravēšanas iekārtu. Salīdzinot ar citām tehnoloģijām, piem., mehāniskā iedarbība, herbicīdi vai apstrāde ar liesmu, lāzera izmantošanai ir vairākas priekšrocības:

- Lāzera stara diametrs var būt ļoti mazs – 1 mm un mazāks;
- Lāzera staru var virzīt ar milimetra precizitāti;
- Lāzeru var ieslēgt/izslēgt ļoti ātri un iedarbība uz auga sākas tajā pašā mirklī;
- Nav negatīvas ietekmes uz apkārtējo vidi vai citiem organismiem.

Lāzera izmantošanai ir arī trūkumi, jo optiskām sistēmām traucē vibrācija, putekļi un mitrums, kas ir neatņemama lauksaimniecības tehnikas ikdiena. Lāzerravēšanas galvenais pielietojuma veids izriet no tā stiprajām pusēm – nezāļu ierobežošana ļoti tuvu kultūraugam, kur mehāniskie rīki var kaitēt kultūrauga attīstībai. Tipisks piemērs būtu nesen sadīguši burkāni – mehāniska augsnes kustināšana var traumēt jaunos augus, bet lāzers var tikt galā ar nezāli dažu milimetru attālumā no burkāna.

Baltās balandas dīgsti. Pa kreisi – pirms apstrādes ar lāzeru; pa labi – 24 h pēc apstrādes

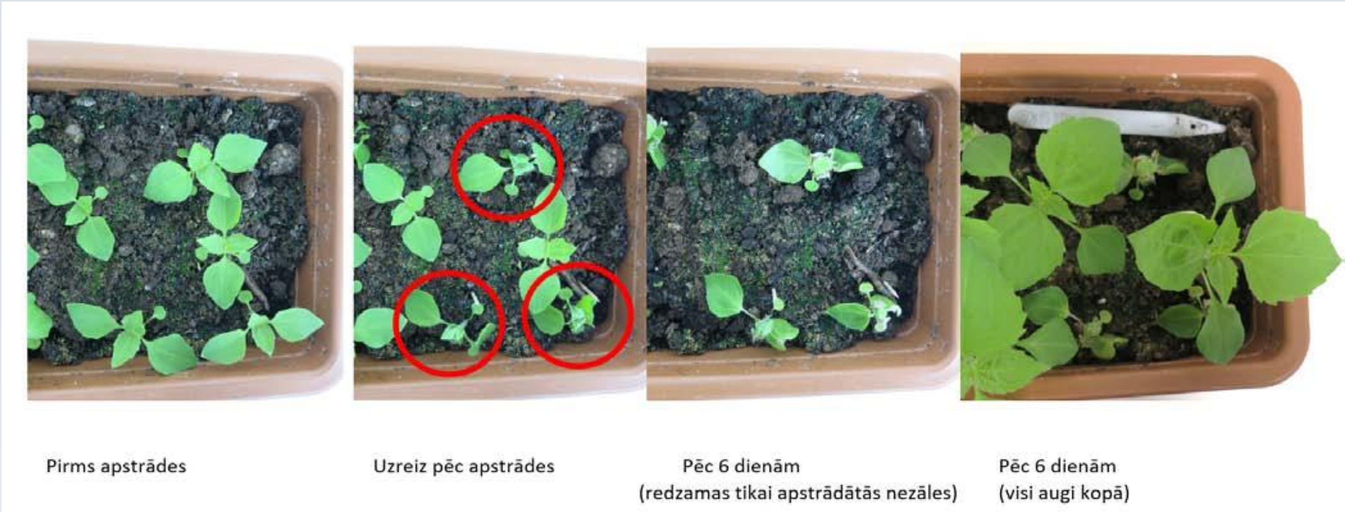
Projekta ietvaros pirmais uzdevums bija noskaidrot, kāda viļņu garuma lāzeru labāk izmantot, jo literatūrā bija aprakstīti dažādi varianti: gan izmantojot redzamās gaismas, gan infrasarkanā spektra lāzerus. Paši veicām eksperimentus ar 445 nm, 1064 nm un 10600 nm gaismas viļņu garuma lāzeriem. Nosliecāmies par labu zilajam lāzeram (445 nm), jo tam bija laba iedarbība uz auga audiem arī pie salīdzinoši nelielas lāzera jaudas. Vēl pozitīvs aspekts ir tajā, ka lāzera stara avots ir diode, kas ir izmēros neliela un noturīga pret vibrācijām.

Nākamais solis bija noskaidrot optimālo iedarbības ilgumu. Projekta vajadzībām tika iegādāts lāzers ar 12 W jaudu, veicām eksperimentus ar dažādu apstrādes laiku. Noskaidrojām, ka šāds lāzers atstāj būtisku ietekmi uz lapas audiem jau pie ātruma 150 mm/s, bet pie ātruma 100 mm/s un lēnāk, ietekme ir lielāka – līdz pat pilnīgai auga vai auga daļas nogriešanai.

Ir dažādas pieejas augu apstrādei, piemēram, mēģināt trāpīt auga kātiņam vai iznīcināt augšanas konusu. Mūsu pieeja bija: apstrādāt visu nezāles zaļo virsmu (skatoties no augšas), t.i., sašķērējot augu. Atkarībā no nezāles izmēriem, griezuma līnijas var izvietot 1 mm attālumā vai tālāk vienu no otras. Veicām eksperimentus arī ar dažādiem griezuma līniju izkārtojumiem – zig-zag veidā un spirāles veidā.

Lāzera apstrādes rezultāts ir atkarīgs no auga attīstības stadijas un morfoloģiskajām īpašībām - jo lielāks augs un biezākas, sulīgākas lapas, jo ilgāk jāveic apstrāde. Līdzīgi ar ilgtermiņa efektu – veicot apstrādi dīgļlapu stadijā vai pie pirmajām īstajām lapām, augu ir iespējams pilnībā iznīcināt. Apstrādājot lielākus augus, novērojām to, ka nezāles spēj veidot jaunas lapas un ataugt, tomēr to attīstība bija būtiski aizkavēta. Attēlā var labi redzēt, ka neapstrādātie augi turpinājuši augt, bet apstrādātās nezāles praktiski apstājušās savā attīstībā. Turklāt šajā eksperimentā, tika apstrādāta tikai augu centrālā daļa.

Lāzerravēšana ir jauns pētniecības virziens Latvijā un arī pasaulē nav daudz zinātnieku un inženieru grupu, kas strādā pie šiem risinājumiem, tādēļ daudzas specifiskās lietas uzzinām tikai caur savu pieredzi. Šobrīd var droši apgalvot, ka lāzeriem būs vieta lauksaimniecībā, jo precizitātes un ātruma ziņā ar tiem grūti sacensties. Te gan jāpiezīmē, ka vispirms ir nepieciešami lauka iz-



Eksperimenta rezultāti apstrādājot ar lāzeru vidēji lielus sīkziedu sīkgalvītes augus. Ar sarkanu apvilkti apstrādātie augi.

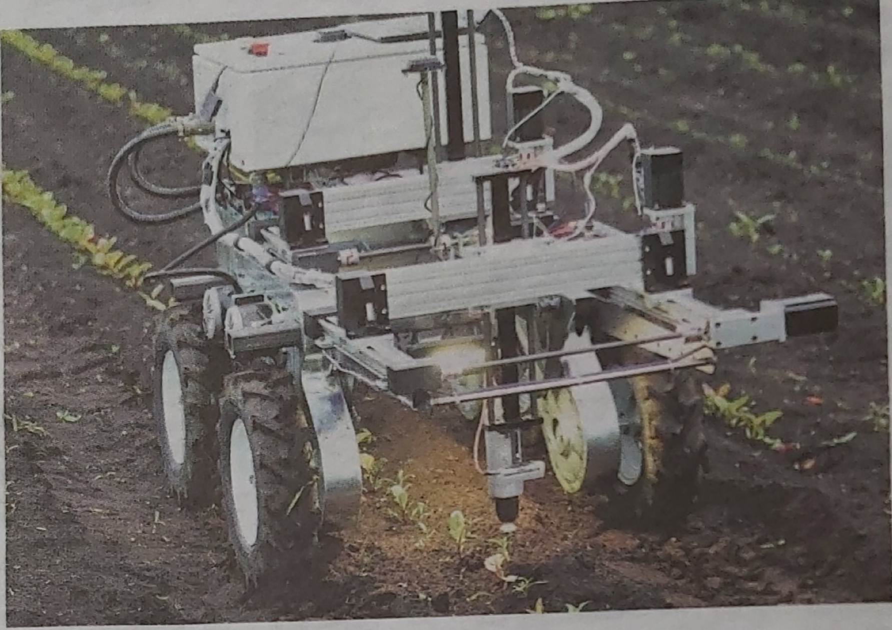
mēģinājumu rezultāti, kas arī varētu ieviest savas korekcijas tam, cik ātri iekārtas nonāks pie gala lietotāja. Visdrīzāk šī nebūs tehnoloģija, kas viena pati aizvietos visus citus nezāļu ierobežošanas veidus, jo šobrīd izskatās, ka tā nav īsti piemērota lielu platību apstrādei. Visdrīzāk lāzerravēšana tiks kombinēta ar citām tehnoloģijām, piemēram, tuvu kultūraugam tiek veikta lāzerravēšana, bet rindstarpās – mehāniskā apstrāde.

Projekta RONIN ietvaros izstrādātais precīzās ravēšanas robots

Zemnieks "Robis"

LLU pētnieks Jānis Jaško veido nezāļu ravēšanas robotu

ANDRIS OZOLIŅŠ



"Robis" spēj atpazīt sešus kultūraugus – bietes, burkānus, rutkus, redīsus, ķirbjus un cukīni.

PUBLICITĀTES FOTO

"Strādājot zinātniskajos projektos, secināju, ka no pētniecības man visvairāk patīk praktiskā daļa – jaunās atziņas vai izstrādātās tehnoloģijas ieviešana dzīvē. Izrādās, ar to iet diezgan grūti gan Latvijā, gan citur pasaulē, jo tas prasa citu veidu prasmes un biznesa "piesitienu", kas bieži vien zinātniekiem nepiemīt," atklāj Jānis Jaško. Šobrīd viņš strādā LLU augu aizsardzības zinātniskajā institūtā "Agrihorts", kas augļu dārzu īpašniekus konsultē par slimību, kaitēkļu un nezāļu ierobežošanu, it īpaši ar videi draudzīgām metodēm.

Ar pētījumiem palīdz lauksaimniekiem

Jānis aktīvi darbojas vairākos pētījumos. Vēl viņš sadarbībā ar LU Bioloģijas institūtu, "Kliģēnu" saimniecību un "Getliņi Eko" meklē labākos veidus, kā ar bioloģiskām metodēm ierobežot plaši izplatīto siltumnīcu kaitēkli – baltblusiņu. Tāpat zinātnieki pēta, kā siltumnīcās apputeksnēt augus ziemā, kad kamenes neaktīvas.

"Robis" rukās vienmēr

Laukos trūkst sezonas darbaroku, arī strādājošo atalgojums ceļas. Tāpēc jāmeklē alternatīva ravēšanai ar rokām. Vispirms zinātnieki izveidoja komandu, kas pārzina vajadzīgās jomas: programmēšanu, iekārtu konstruēšanu, datorredzi, bioloģiju, elektroniku un lauksaimniecību. Pie iekārtas izstrādes strādāja speciālisti no LLU Tehniskās fakultātes, Elektronikas un datorzinātņu institūta un "Agrihorta". Laukus, kur apmācīt un izmēģināt robotu, atvēlēja trīs bioloģiskās saimniecības.

"Meklējot, vai nav pieejami kādi gatavi rīki, kas spētu tikt galā ar nezālēm, kas aug tuvu kultūraugam, secināju, ka īsti nekas nav atrodams," atceras zinātnieks. "Ir dažādi mehāniskie rīki, ko veiksmīgi var izmantot, lai kultivētu rindu starpas vai starpvadzes, bet kas tāds, kas aizvietotu roku darbu, īsti nebija atrodams. Nolēmām izveidot specializētu robotu. Lai tiktu galā ar mazajām nezālēm pavisam tuvu kultūraugam, izvēlējāmies lāzeru kā ļoti precīzu rīku. Ar lielā*kām nezālēm nedaudz tālāk no kultūrauga tiek galā neliels, rotējošs rīks.*"

Šķirt sēklu no pelavām

Pirmais zinātnieku uzdevums bija iemācīt datoram atšķirt augus gan savā starpā, gan no nezālēm. Tam izmantoja daudz attēlu, kuros ar rāmīti ir apvilkti izvēlētie augi, piemēram, burkāni. Tad visus šos attēlus ielādēja speciālā programmā, ko bieži apzīmē par "neironu tīkliem", jo savā būtībā tie atgādina cilvēka smadzeņu darbības principu. Programma mēģina atrast sakarības, ar ko burkāns atšķiras no citiem augiem, kas ir redzami attēlā. "Robis" šobrīd spēj atpazīt sešus kultūraugus – bietes, burkānus, rutkus, redīsus, ķirbjus un cukīni. Tas ir apmācīts atpazīt arī vairākas bieži sastopamās nezāļu sugas. Pēc tam kad nezāles ir atpazītas, mazākās tiek iznīcinātas ar lāzera palīdzību, bet lielās izravē rotējošais mehānisms.

"Robis" prot braukt pēc GPS koordinātām un, virzoties pa vagu, "piestūrēt" atbilstoši vagai. Līdz projekta pirmā etapa beigām vēl jāpabeidz dažādas tehniskas nianses, lai iekārta darbotos, kā plānots. Tālāk jāturpina apmācīt "Robim" atpazīšanas algoritmu, lai uzlabotu precizitāti esošajiem, kā arī atpazīstamo sarakstam pievienot citus kultūraugus. Plānots aktīvi sadarboties ar zemniekiem, lai saņemtu informāciju par lietām, ko nepieciešams uzlabot.

"Šajā procesā daudz ko iemācījāmies, jo augu attēlu atpazīšana, kā izrādījās, ir krietni mazāk izpētīts lauciņš, salīdzinot, piemēram, ar sejas atpazīšanu vai auto atrašanu attēlos, kam lielās korporācijas pasaulē ir veltījušas daudz laika un resursu. Pēc pirmajiem testiem atradām dažādus faktorus, piemēram, situācija, kad daļa attēla ir vairāk izgaismota nekā otra daļa, kas var būtiski "samulsināt" datoru, tāpēc daudz laika veltījām lai izveidotu mūsu programmu pēc iespējas "gudrāku". Mūsu misija ir izstrādāt tehnoloģiju, kuru var izmantot ikvienā zemnieku saimniecībā. Tā kā Latvijas zinātnieki ir vieni no nedaudzajiem, kas pasaulē strādā šajā jomā, ceram būt pirmie, kuriem izdosies lāzeru ravētāju novest līdz gatavam, zemniekiem ikdienā izmantojamam produktam," *smaida* Jānis.

VĒRTĒJUMS:
Robots atvieglotu vienmuļo darbu

● **Andris Mangulis,** bioloģiskās saimniecības "Atvases" īpašnieks: "Nezāļu ravēšana ir smags un vienmuļš darbs, kas jāveic, neskatoties uz laika apstākļiem. Piedevām ravēšana notiek tikai pāris mēnešus gadā, un ir arvien grūtāk uz šo īso brīdi atrast strādniekus. Iespēja ar robota palīdzību atvieglot smago darbu ir teicama perspektīva. Tā ļautu arī bioloģiskajiem un biodinamiskajiem laukkopjiem apsaimniekot lielāku platību un iegūt lielākas veselīgas pārtikas ražas."

PRECĪZĀS TEHNOLOĢIJAS CĪŅĀ PRET NEZĀLĒM

Dzīvē nav labā un sliktā. Katram priekšmetam, dzīvai būtnei, apstākļiem ir sava nozime, katrs pilda savu lomu, taču ražošanas sektorā uzsvars tiek likts uz racionālu resursu izmantošanu, lai pēc iespējas efektīvāk saražotu izejvielas gala produkcijai. Ir lietas, kuras ir iespējams ietekmēt, taču ir lietas, piemēram, dabas spēki, ko ietekmēt cilvēki pagaidām neprot, un varbūt tas arī ir labi.

ANDREJS KOSTROMINS,
pētnieks, Latvijas Lauksaimniecības universitāte

Lauksaimniecībā viena no lielākajām problēmām ir nezāles, kas tiešā veidā ietekmē ražu un tādējādi arī ienākumus no hektāra. Par laimi, nezāles nav tas pats kas pārlieku liels un ilgstošs karstums vai lietavas, un nezāles cilvēks ir iemācījies kontrolēt.

Tradicionāli nezāles ierobežoja ar mehānisku ravēšanu, vēlāk ar ķīmiskām vielām – herbicīdiem. Vispārīgi uzsmidzināt *ķīmiju* ir daudz vienkāršāk, jo nav precīzi jātrāpa nezālei atšķirībā no mehāniskās ravēšanas, kur jābūt precīzam fiziskam kontaktam. Turklāt, ja runā par ravēšanu ar rokām, tad jāņem vērā papildu apgrūtinājumi – darbaspēka trūkums un atalgojuma pieaugums arī šajā nozarē. Būsim godīgi – kurš gribētu dienām ilgi ar salīkušu muguru kaplēt hektāriem lielu lauku, pat ja neņem vērā bieži vien ne visai patīkamos laika apstākļus?

Taču arī ar pesticīdiem viss nav tik vienkārši, jo regulas, kas nosaka pieļaujamo ķīmisko vielu daudzumu un apstrādājamo reižu skaitu, kļūst aizvien striktākas, un jāteic – ne bez pamata. Katru gadu pasaulē lauksaimnieki kopumā izsmidzina uz laukiem divus miljonus tonnu pesticīdu 60 miljardu eiro vērtībā, no kuriem paliek atliekvielas augsnē, ūdens sistēmās un pašos augos, kurus pēc tam izmanto lopbarībā vai pārtikas produktu ražošanā.

Projekts robotizētas nezāļu ierobežošanas iekārtas izveidē

Mēdz teikt, ka cilvēkus uz priekšu dzen slinkums, ambīcijas, zinātkāre un citas īpašības, tāpēc notiek nemitīga tehnoloģiju attīstība, tostarp lauksaimniecībā. Latvijas Lauksaimniecības universitātes (LLU) Augu aizsardzības institūts *Agrihorts* ar zinātniskajiem partneriem – LLU Tehnisko fakultāti un Elektronikas un datorzinātņu institūtu – nu jau gandrīz divus gadus īsteno zinātnisko projektu nr. 18-00-A01612-000024 *Robotizētas nezāļu ierobežošanas iekārtas izveide (RONIN)*. Projekta galvenais rezultāts paredz izstrādātu prototipu pašbraucošai robotizētai iekārtai, kas ir aprīkota ar borta datoru un vajadzīgajiem agregātiem nezāļu ierobežošanai. Borta dators ir aprīkots ar mākslīgo intelektu, un ir plānots to apmācīt atpazīt noteiktas nezāļu sugas un noteiktus kultūraugus.

Ideja par robotiem, kas veic noteiktus lauksaimniecības uzdevumus, nav jauna, tās pirmsākumi meklējami pirms vairākiem gadu desmitiem, taču līdz pat mūsdienām ne visiem uzdevumiem ir atrasti sekmīgi risinājumi, kas no laboratorijas eksperimentiem nonākuši līdz ražošanai un lietošanai reālos lauka apstākļos. Viens no šādiem uzdevumiem ir nezāļu ravēšana, kur galvenie izaicinājumi ir pietiekams apstrādes ātrums, apstrādes precizitāte, noturība pret ārējiem laika apstākļiem, mehāniskām vibrācijām un ekonomiski pamatota gala iekārtas cena.

Ravēšanu var iedalīt starprindu un iekšrindu ravēšanā (starp augiem rindas ietvaros). Starprindu ravēšanā jau eksistē mehāniski agregāti, kas darbojas pietiekami efektīvi un atkarībā no tehniskā izpildījuma ierobežo nezāles izraujot, nogriežot, sasmalcinot vai aprokot. Lai arī iekšrindu ravēšanā ir izstrādāti dažādi mehāniskie risinājumi un tie ir pieejami tirgū, piemēram, vācu uzņēmuma *K.U.L.T. Kress* tā sauktais pirkstiņravētājs *(fingerweeder)*, iekšrindu ravēšana ir sarežģītāka, jo process ir jāveic precīzi un uzmanīgi, lai nesabojātu kultūraugu. Turklāt eksistē kultūraugi, piemēram, burkāni un bietes, kas augšanas sākuma stadijās ir īpaši jutīgi pret mehānisku iedarbību, tāpēc mazākā auga sakņu sistēmas izkustināšana var būtiski ietekmēt turpmāko auga attīstību. Zinātnieki ir radījuši dažādas tehnoloģijas cīņai ar nezālēm.

Apstrāde ar ūdens strūklu

Jau 1975. gadā eksperimentāli tika novērtēta tievas ūdens strūklas spēja nogriezt/sabojāt augu. Rezultāti parāda, ka aptuveni 60–70% no augiem tika būtiski sabojāti, ja to kātiņa diametrs nepārsniedza 1,5 mm, savu-

Augstspiediena (1000 bar) ūdens strūklas nezāļu ierobežošanas iekārta *GrassKiller Mono* no *Caffini*.

Iekārtu var izmantot dažādiem kultūraugiem (www.caffini.com/media).

kārt augiem ar kātiņa diametru 3 mm efekts nebija novērojams.

Tehnoloģija ir nonākusi līdz gala lietotājam. Piemēram, itāļu uzņēmums *Caffini* piedāvā dažādas mūsdienīgas augstspiediena ūdens strūklas nezāļu ierobežošanas iekārtas, kas paredzētas vīnogu audzētājiem un citiem augļu kokiem un krūmiem. Pateicoties lielajam 1000 bāru spiedienam, iekārta spēj tikt galā gan ar tām nezālēm, kas atrodas virs augsnes, gan ar tām, kas vēl tikai dīgst. Šī iekārta ir piemērota tikai pietiekami lieliem kokiem un krūmiem, kuriem spēcīgā ūdens strūkla nespēj kaitēt.

Apstrāde ar liesmu

Gāzes degļu nezāļu ierobežošanas iekārta kultūrauga rindām no *Steam Weeding Ltd* (www.physicalweeding.com/flameweeding).

To var lietot: pirms sēšanas; pēc sēšanas, ja nezāles sadīgst ātrāk par kultūraugu; pēc kultūraugu sadīgšanas, lietojot aizsargvairogu, ja kultūraugs ir jutīgs pret paaugstinātu temperatūru. Piemēram, Jaunzēlandes uzņēmums *Steam Weeding Ltd* lepojas ar vismaz 30 gadu pieredzi šāda tipa iekārtu projektēšanā un izstrādē. Uzņēmums piedāvā gan vieglas cilvēkam paredzētas iekārtas rokas degļa variantā, gan lielas, karināmas aiz traktora. Viņi piedāvā vairākus veidus: visas dobes platumā, tikai kultūrauga rindā vai iekšrindā (piemērots tikai atsevišķiem kultūraugiem).

Visas dobes apstrādes iekārtas pārsvarā mēdz lietot gadījumos, ja starp kultūraugu rindām ir mazs attālums. Rindas apstrāde ļauj paātrināt procesu no divām līdz pat četrām reizēm, salīdzinot ar visas dobes apstrādi. Šādi var ietaupīt traktortehnikas degvielu, gāzi un arī paveikt darbu ātrāk. Rindstarpu apstrādi savukārt veic ar tradicionālajiem kultivatoriem.

Starprindu apstrāde ar liesmu esot izplatīts nezāļu ierobežošanas veids Ziemeļamerikā. To lieto kultūraugiem ar liela diametra stumbru, piemēram, kukurūzai, kokvilnai, kāpostiem, parasti, kad nezāles ir mazas, bet kultūraugs jau pietiekami paaudzies. Šādā veidā pastāv iespēja nodarīt minimālus bojājumus kultūraugam.

Sasaldēšanas metode

1991. gadā pētnieki eksperimentāli ir noteikuši nepieciešamās šķidrā slāpekļa un ogleķļa dioksīda devas, lai novājinātu un tādējādi būtiski ietekmētu nezāļu augšanu. Šī metode gan nav guvusi pietiekamu atzinību, un iekārtu tirgū neizdodas atrast pat prototipa līmenī.

Apstarošana ar mikroviļņiem

Mikroviļņus izstarojoša iekārta nezāļu un to sēklu ierobežošanai, Melburnas universitāte (www.futurity.org/microwaves-weeds-2177112-2).

Mikroviļņu radiācija jeb starojums spēj iznīcināt nezāles pēc līdzīga principa, kā notiek ūdens daļiņu sildīšana mikroviļņu krāsnīs. Ūdens, kas atrodas nezāļu šūnās, strauji uzsilst un izplešas, tādējādi pārraujot auga šūnu sieniņas, un nezāle iet bojā. Melburnas universitātes pētnieki Austrālijā ir izstrādājuši iekārtu ar mikroviļņu izstarotājiem, vērstiem pret augsni. Iekārtu var izmantot gan pret sadīgušajām nezālēm, gan pašas augsnes apstrādei pirms kultūraugu sēšanas, jo mikroviļņi spēj iedarboties līdz pat pieciem centimetriem augsnē un *uzvārīt* nezāļu sēklas.

Iekārta nelabvēlīgi ietekmē arī derīgo baktēriju daudzumu augsnē, taču zinātnieki norāda, ka mēneša laikā to apjoms normalizējas. Pēc kultūraugu iesēšanas esošā izpildījumā iekārta ir piemērota tikai starprindu apstrādei, jo mikroviļņu apstrādes laukums ir salīdzinoši liels un ar to nevar precīzi notēmēt tikai uz konkrētām nezālēm, nenodarot kaitējumu pašiem kultūraugiem.

Ietekme ar infrasarkano starojumu

Infrasarkanā starojuma nezāļu ierobežošanas iekārta no *Adler* (https://adler-arbeitsmaschinen.de/en/products/adlerheater-10001300).

Līdzīgi kā citām termiskām metodēm, arī infrasarkanā starojuma mērķis ir sakarsēt nezāles, lai sabojātu to audus tālākai attīstībai. Tirgū ir pieejamas salīdzinoši nelielas iekārtas, kas paredzētas ceļmalu, taku un bruģa apstrādei pret nezālēm. Šāda iekārta spēj apstrādāt 2800–4200 m^2 atkarībā no nezāļu daudzuma.

Ir arī lielām platībām piemērotas iekārtas, piemēram, ražotāja *HOAF* iekārtas, ar kurām uzturēt melno papuvi pavasarī pirms dārzeņu sējas. Arī šajās iekārtās tiek dedzināta gāze, taču tā netiek vērsta tieši pret darba virsmu, bet gan uz speciāliem keramiskajiem sildītājiem, kas tālāk izstaro siltumu infrasarkanā starojuma veidā.

Apstrāde ar gaisa plūsmu

Gaisa plūsmas nezāļu ierobežošanas iekārta no *Egedal Maskinfabrik A/S* (https://egedal.dk/en/produkter/blowing-machine-type-bm).

2000. gadā zinātnieki prezentēja sistēmu, kurā no abām vagas pusēm caur sprauslām aptuveni 2 cm zem augsnes virskārtas tiek pūsta spēcīga gaisa plūsma, kas izrauj nezāli no augsnes. Līdzīgu metodi izmanto dāņu uzņēmums *Egedal Maskinfabrik A/S*. Ar jūgvārpstas palīdzību tiek piedzīta viena vai divas liela izmēra gaisa turbīnas, kas pa caurulēm nogādā gaisu līdz sprauslām. Sprauslas ir novietotas pamīšus no abām rindas pusēm virs augsnes. Konkrēto iekārtu uzņēmums piedāvā nezāļu iznīcināšanai starp rožu krūmiem.

Apstrāde ar elektrisko triecienu

Augstsprieguma (7 kV) nezāļu ierobežošanas iekārta *XPower* no *Zasso* (www.fwi.co.uk/machinery/technology/digital-weed-zapper-offers-alternative-to-chemical-herbicides).

2002. gadā prezentēta sistēma, kur zinātnieki pakļauj kādu no nezāles lapām 15 kV izlādei, tādējādi mazas nezāles tiek pilnībā iznīcinātas, taču lielākām nezālēm tiek bojāta tikai konkrētā lapa.

Pirms aptuveni diviem gadiem Eiropas lauksaimniecības iekārtu tirgū kļuva pieejama elektriskā nezāļu ravēšanas iekārta *XPower.* Tā ģenerē līdz pat 7 kV maiņspriegumu noteiktā frekvencē un ar speciālu elektrodu (elektrību vadošu stieņu vai plākšņu) palīdzību nogādā enerģiju uz nezālēm. Īsais, bet spēcīgais elektrotrieciens iznīcina nezāļu audu sistēmu, kas nodrošina ūdens un barības vielu transportēšanu, tādējādi nezāles sāk novīst. Ietekme uz kukaiņiem, baktērijām un sliekām esot niecīga. Šobrīd iekārtas galvenais lietojuma veids ir kartupeļu lakstu likvidēšana, lai apturētu kartupeļu bumbuļu augšanu vēlamajā izmērā, saglabātu klientam pievilcīgu bumbuļu izskatu un nepieļautu infekciju izplatīšanos, līdz raža tiek novākta.

Līdzīgu sistēmu attīsta uzņēmums *RootWave,* kuru iekārtas izmantojamas gan individuālu augu, piemēram, latvāņu, ierobežošanai, gan pie traktora liekamas iekārtas nezāļu ierobežošanai augļudārzos.

Apstrāde ar karstu ūdeni/tvaiku

Karstā ūdens/tvaika nezāļu ierobežošanas iekārta no *M.M.srl* (www.vegemac.be/en/shop/products/i/750201).

Nezāles termiskā apdeguma dēļ iet bojā. Tirgū ir pieejamas dažādas iekārtas, kas sadedzina gāzi, dīzeļdegvielu vai eļļu un sasilda ūdeni, un izsmidzina to šķidrā vai tvaika veidā uz nezālēm.

Apstrāde ar lielas jaudas lāzeru

Ar lāzeru aprīkots robots nezāļu ierobežošanai no *dCentralized Systems* (www.geekwire.com/2018/dcentralized-systems-llc).

Te ir iespējamas vairākas pieejas: a) ar leņķi pavērstu lāzera staru nogriezt nezāli ar visu kātu; b) ar perpendikulāru lāzera staru ietekmēt tikai nezāles jutīgāko daļu centrā; c) ar mazāk jaudīgu starojumu veikt vienmērīgu visas nezāles virsmas termisku apstrādi. Katrai no pieejām ir priekšrocības un trūkumi.

Kāta nogriešana ir ļoti efektīva, un to var veikt nosacīti aptuvenā augstumā, taču, griežot leņķī, var trāpīt arī kultūraugam, ja tas atrodas blakus. Nezāles jutīgākās daļas ietekmēšana centrā ar perpendikulāru staru ir visdrošākā un efektīvāka metode, taču ar datorredzes un mākslīgā intelekta palīdzību noteikt nezāles centru ir izaicinošs uzdevums, turklāt āra apstākļos vismazākā vēja brāzma izkustinās nezāli un lāzers tai netrāpīs. Kā pēdējā atliek vienmērīga nezāles virsmas apstrāde ar perpendikulāru mazākas jauda starojumu. Lai gan šī metode ir lēnāka par pirmajām divām, jo jāveic daudz vairāk griezumu auga virsmā, tās galvenā priekšrocība ir saglabāta drošība attiecībā uz tuvu blakus esošo kultūraugu neietekmēšanu un izslēdz iespēju, ka lāzers netrāpīs nezālei vēja ietekmē.

Kopumā lāzera pieejas galvenās priekšrocības ir ļoti augstā precizitāte un iedarbības ātrums. Lāzera punkta izmērs ir mazāks par milimetru, un to ir iespējams ārkārtīgi precīzi pozicionēt telpā ar dažādiem mehāniskiem un optiskiem paņēmieniem.

Nezāļu apstrādes veidu kopsavilkums

Apstrādes veids	Priekšrocības	Trūkumi
Ar ūdens strūklu	Tiek lietots ūdens bez iepriekšējas sildīšanas.	Ir mehānisks kontakts ar augsni. Piemērots tikai kultūraugiem ar pietiekami lielu stumbru. Regulāri jāpapildina ūdens tvertne. Nav precīza mērķēšana uz nezāli
Ar liesmu	Piemērots dažādām kultūraugu attīstības stadijām. Nav mehāniska kontakta ar augsni	Nepieciešams dedzināt gāzi. Regulāri jāmaina gāzes baloni. Maziem kultūraugiem jālieto aizsargvairogs, lai termiski nesabojātu augus. Nav precīza mērķēšana uz nezāli.
Ar mikroviļņiem	Nav mehāniska kontakta ar augsni. Nav jāveic regulāras uzpildes, jo darbojas ar traktortehnikas enerģiju.	Pagaidām paredzēts tikai lauka apstrādei pirms kultūraugu sēšanas un starpvagu apstrādei pēc kultūraugu sēšanas. Uz laiku samazina derīgo baktēriju daudzumu augsnē. Nogalina kukaiņus, sliekas un citus bezmugurkaulniekus. Nav precīza mērķēšana uz nezāli.
Ar infrasarkano starojumu	Nav mehāniska kontakta ar augsni.	Nepieciešams dedzināt gāzi. Regulāri jāmaina gāzes baloni. Nav precīza mērķēšana uz nezāli. Nav precīza mērķēšana uz nezāli.
Ar gaisa plūsmu	Nav mehāniska kontakta ar augsni (ir ietekme uz virskārtu). Nav jāveic regulāras uzpildes, jo darbojas ar traktortehnikas mehānisko enerģiju caur jūgvārpstu.	Nav precīza mērķēšana uz nezāli. Daļēji ietekmē nezāļu sēklu izplatību augsnes virskārtā gaisa plūsmas dēļ. Pagaidām ierobežots kultūraugu lietojums.
Ar elektrisko spriegumu	Nav mehāniska kontakta ar augsni. Nav jāveic regulāras uzpildes, jo darbojas ar traktortehnikas mehānisko enerģiju caur jūgvārpstu (ir ģenerators). Iedarbība norisinās ne tikai nezāles virszemes daļā, bet arī sakņu sistēmā.	Pagaidām mērķēšana uz nezāli nav precīza. Nedaudz ietekmē kukaiņu un citu augsnes bezmugurkaulnieku, kā arī baktēriju daudzumu. Pagaidām ierobežots kultūraugu lietojums.
Ar karstu ūdeni/tvaiku	Piemērots dažādām kultūraugu attīstības stadijām. Nav mehāniska kontakta ar augsni.	Nepieciešams dedzināt gāzi, dīzeļdegvielu, eļļu vai citu degvielas veidu. Regulāri jāpapildina gan degvielas rezerves, gan ūdens tvertne. Nav precīza mērķēšana uz nezāli.
Ar augstas jaudas lāzeru	Piemērots dažādām kultūraugu attīstības stadijām. Nav mehāniska kontakta ar augsni. Var realizēt bez lielām kustīgām mehāniskām daļām. Liels apstrādes ātrums. Precīza mērķēšana un ietekme.	Sarežģīts mākslīgā intelekta apmācības process līdz brīdim, kad iekārta var nonākt tirgū. Mākslīgais intelekts jāapmāca katram kultūraugam.

RONIN projekta risinājums

FOTO: VILNIS PĪRS

Projekta *Robotizētas nezāļu ierobežošanas iekārtas izveide* ietvaros izstrādātā iekārta nezāļu apstrādei ar lāzeru un precīzo mehānisko agregātu.

Zinātnieki un uzņēmumi jau labu laiku cenšas atrast pietiekami efektīvu un finansiāli izdevīgu risinājumu cīņā ar nezālēm. LLU *RONIN* projekta komanda veiksmīgi turpina attīstīt lāzera izmantošanu cīņā ar nezālēm, jo lāzeru tehnoloģijas ir kļuvušas daudz pieejamākas un tām ir būtiskas priekšrocības salīdzinājumā ar citām metodēm: zibenīgs ātrums, ļoti augsta precizitāte un iedarbība bez fiziska kontakta ar augsni. Lāzera starojums pēc būtības ir gaisma, un, kā zināms, pagaidām cilvēki neko ātrāku par gaismu nav atklājuši. a

Roboti lauksaimniecībā

Darba roku trūkumu lauksaimniecības sektorā ar katru gadu novēro arvien vairāk. Īpaši izteikti tas ir augļu un dārzeņu saimniecībās, kur ražas novākšanas laikā aktuāls roku darbs. Bioloģiskajās saimniecībās būtiski cilvēkresursi ir nepieciešami arī nezāļu ierobežošanai, un šim aspektam pievērsušies diezgan daudzi uzņēmumi.

TEKSTS: Mg. sc. env. Jānis JAŠKO, LLU Augu aizsardzības zinātniskā institūta *Agrihorts* pētnieks. Publicitātes foto

Par robotu izmantošanu lauksaimniecībā tiek runāts jau sen, taču tikai pēdējos gados autonomas iekārtas ir kļuvušas par audzētājiem reāli pieejamu risinājumu. Lai arī izstrādes process turpinās un lielai daļai uzņēmumu joprojām nav izdevies izveidot ekonomiski dzīvotspējīgus risinājumus, jaunākie sasniegumi attēlu atpazīšanas programmatūrā un augstas precizitātes GPS ir ļāvuši vairākiem uzņēmumiem laist tirgū lauksaimniecības robotus, kas reāli strādā.

Naio

Viens to šādiem uzņēmumiem ir franču kompānija *Naio*. Viņu klāstā ir vairāki roboti, bet izceļams ir *Dino* – autonoms ravēšanas robots, kas, izmantojot RTK-GPS, sasniedz braukšanas precizitāti 5 cm, spēj atpazīt kultūraugu un virzīt rušināšanas agregātus tam iespējami tuvu. Iekārta spēj apstrādāt līdz 4 ha dienā un darbojas ar akumulatoriem. Vairāk nekā 20 *Dino* robotu darbojas saimniecībās Eiropā un ASV. *Dino* galvenokārt izmanto dārzeņu audzētāji, it īpaši salātu laukos, jo laukā dēstītie salāti ir piemēroti automātiskajiem ravēšanas rīkiem, kā arī ieņēmumi no hektāra ir pietiekoši augsti, lai robotu izmantošana atmaksātos. Sadarbībai ar zemniekiem *Naio* ir vairāki veidi: robotu kopā ar zemnieka izvēlētajiem ravēšanas rīkiem iespējams gan iznomāt noteiktam periodam, gan iegādāties. *Dino* robots bez ravēšanas aprīkojuma zemniekam izmaksās aptuveni 130 000 EUR.

Franču kompānijas Naio autonomais ravēšanas robots *Dino* (foto: *naio-technologies.com*).

Farmdroid

Robots, kas pats iesēj kultūraugu un pēc tam tiek galā ar nezālēm, ir pieejams dāņu uzņēmuma *Farmdroid* piedāvājumā. Modelis FD20 piemērots gan dārzeņiem (bietēm, sīpoliem), gan rapšiem un citiem kultūraugiem. Šobrīd jau vairāk nekā 50 robotu darbojas 7 Eiropas valstīs. Zemnieki īpaši novērtējuši robota lietderību *Covid-19* laikā, kad sezonas strādnieku piesaiste vairākās ES valstīs bija īpaši problemātiska.

Šim robotam ir liels saules bateriju panelis, kas nodrošina ilgstošu darbību. Pēc ražotāja teiktā, piemērotos apstākļos robots spēj pat vairākus mēnešus darboties bez papildu uzlādes. Robota darba platums ir 3 m, un tas tiek kombinēts ar dažādiem sēšanas un kultivēšanas agregātiem. FD20 cena ir ~65 000 EUR.

Dāņu uzņēmuma *Farmdroid* robota modelis FD20 (foto: *farmdroid.dk*).

LLU Augu aizsardzības zinātniskā institūta *Agrihorts* nezāļu robots *Robis* (foto: Vilnis Pīrs).

Robis

Latvijā par lauksaimniecības robotiem ne tikai runā, bet arī tiek veikts nozīmīgs pētniecības un izstrādes darbs. Latvijas Lauksaimniecības universitātes Augu aizsardzības zinātniskais institūts *Agrihorts* sadarbībā ar partneriem no LLU Tehniskās fakultātes un Elektronikas un datorzinātņu institūta divus gadus īsteno zinātnisko projektu Nr. 18-00-A01612-000024 *Robotizētas nezāļu ierobežošanas iekārtas izveide*. Projekta ietvaros ir izstrādāts prototips nezāļu robotam, kas izmanto lāzeru un precīzi pozicionētu rotējošo rīku, lai iznīcinātu nezāles. Robots, kas nu jau ir ieguvis vārdu *Robis*, ir aprīkots ar RTK-GPS iekārtām, lai precīzi pārvietotos pa iepriekš sastādīto maršrutu, kā arī vairākām kamerām, lai atpazītu vagu virzienu, kā arī identificētu augus. To visu vada jaudīgs borta dators, kas ir aprīkots ar mākslīgo intelektu un spēj atpazīt kultūraugus, uz kuriem tas ir apmācīts, – burkānus, bietes, cukīni, ķirbjus, rutkus un redīsus. Atšķirībā no citiem robotiem iekārtā izmantotais lāzers spēj ļoti precīzi apstrādāt tās nezāles, kuras atrodas ļoti tuvu kultūraugam un kur mehāniskie rīki netiek klāt. Testi ar iekārtu pie zemniekiem turpināsies 2021. gadā, tā ka audzētāji, kas ir ieinteresēti redzēt *Robi* uz sava lauka, var sazināties ar LLU pētnieku Jāni Jaško.

Ilgstoši valdīja neziņa, vai ES striktā regulējuma apstākļos autonomo lauksaimniecības robotu ražotājiem vispār izdosies sertificēt lielos robotus tā, lai katram no tiem blakus nevajadzētu atrasties cilvēkam – robota uzraugam. 2020. gada beigās *Naio* izdevās sertificēt *Dino* modeli, un, pēc ražotāja teiktā, tagad tas bez tiešas cilvēka uzraudzības drīkstēs strādāt uz lauka. Sagaidāms, ka tuvākajos gados arvien vairāk ražotāju sekos šim paraugam un, iespējams, uz laukiem redzēsim *ganoties* robotu barus.

Nu jau vairākus gadus Tulūzā (Francijā) tiek rīkota lauksaimniecības robotiem veltīta starptautiska izstāde – *FIRA International Forum of Agricultural Robotic*, kur uz inovācijām vērsti saimnieki, kuri apsver domu par robotu savā saimniecībā, var iepazīt tuvāk jaunākos sasniegumus lauksaimniecības robotizācijā. SL

NACIONĀLAIS ATTĪSTĪBAS PLĀNS 2020
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Eiropas Lauksaimniecības fonds lauku attīstībai
Atbalsta Zemkopības ministrija un Lauku atbalsta dienests

Fails "app.c"

```
/*******************************************************************************
  MPLAB Harmony Application Source File

  Company:
    Microchip Technology Inc.

  File Name:
    app.c

  Summary:
    This file contains the source code for the MPLAB Harmony application.

  Description:
    This file contains the source code for the MPLAB Harmony application.  It
    implements the logic of the application's state machine and it may call
    API routines of other MPLAB Harmony modules in the system, such as drivers,
    system services, and middleware.  However, it does not call any of the
    system interfaces (such as the "Initialize" and "Tasks" functions) of any of
    the modules in the system or make any assumptions about when those functions
    are called.  That is the responsibility of the configuration-specific system
    files.
 *******************************************************************************/

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 *******************************************************************************/
// DOM-IGNORE-END

// *****************************************************************************
// *****************************************************************************
// Section: Included Files
// *****************************************************************************
// *****************************************************************************

#include "app.h"
#include "M2M_interface.h"
#include "RONIN_CNC.h"
#include "UDPComm/PIC32_Harmony/udpcomm.h"


// *****************************************************************************
```

```c
// *****************************************************************************
// Section: Global Data Definitions
// *****************************************************************************
// *****************************************************************************


// *****************************************************************************
/* Application Data

  Summary:
    Holds application data

  Description:
    This structure holds the application's data.

  Remarks:
    This structure should be initialized by the APP_Initialize function.

    Application strings and buffers are be defined outside this structure.
*/

APP_DATA appData;

// *****************************************************************************
// *****************************************************************************
// Section: Application Callback Functions
// *****************************************************************************
// *****************************************************************************

/* TODO:  Add any necessary callback functions.
*/

// *****************************************************************************
// *****************************************************************************
// Section: Application Local Functions
// *****************************************************************************
// *****************************************************************************

uint8_t buff[20];
/* TODO:  Add any necessary local functions.
*/
static void LedTask( void )
{

}

void Test_Callback ( uintptr_t context, uint32_t currTick )
{
    //SYS_CONSOLE_PRINT("Motor actual velocity: %d \r\n", CO_OD_RAM.motorActualVelocity1);
#ifdef RONIN_CM_V1_4
    static int state = 0;
    switch(state)
    {
        case 0: LED_RToggle(); break;
        case 1: LED_GToggle(); break;
        case 2: LED_BToggle(); break;
    }
    state++;
   // SYS_CONSOLE_PRINT("State: %d\r\n", state);
    if (state == 3) state = 0;
#endif
}

void Timer50ms_Callback ( uintptr_t context, uint32_t currTick )
```

```
{

#if USE_CAN == 1
    bool CO_OD_RAM_tst = false;
    int16_t speed = 0;//(int16_t)CO_OD_RAM.readAnalogueInput16Bit[1];
    static int pwmStep = 40;

    speed = (speed << 1); //conversion from 15bit to 16bit signed
    speed /= 2;



//    if(CO_OD_RAM_tst)
//    {
//        SYS_CONSOLE_PRINT("%d\t%d\t%d\n\r",
//                        CO_OD_RAM.readAnalogueInput16Bit[0],
//                        speed,
//                        CO_OD_RAM.readAnalogueInput16Bit[2]);
//    }
//        CO_OD_RAM.writeAnalogueOutput16Bit[0] += pwmStep;
//        if (CO_OD_RAM.writeAnalogueOutput16Bit[0] >= 8000)
//        {
//            pwmStep = -200;
//            CO_OD_RAM.writeAnalogueOutput16Bit[0] = 8000;
//        }
//        else if (CO_OD_RAM.writeAnalogueOutput16Bit[0] <= 0)
//        {
//            CO_OD_RAM.writeOutput8Bit[0] ^= 1;
//            pwmStep = 100;
//            CO_OD_RAM.writeAnalogueOutput16Bit[0] = 0;
//        }
//        else
//        {
//            CO_OD_RAM.writeOutput8Bit[0] &= 0xFE;
//        }
#endif
}

// *****************************************************************************
// *****************************************************************************
// Section: Application Initialization and State Machine Functions
// *****************************************************************************
// *****************************************************************************

/*******************************************************************************
  Function:
    void APP_Initialize ( void )

  Remarks:
    See prototype in app.h.
 */

void APP_Initialize ( void )
{
    /* Place the App state machine in its initial state. */
    appData.state = APP_STATE_INIT;

    /* TODO: Initialize your application's state machine and other
     * parameters.
     */

}
```

```
/*******************************************************************************
  Function:
    void APP_Tasks ( void )

  Remarks:
    See prototype in app.h.
 */

void APP_Tasks ( void )
{

    /* Check the application's current state. */
    switch ( appData.state )
    {
        /* Application's initial state. */
        case APP_STATE_INIT:
        {
            if (SYS_TMR_Status(sysObj.sysTmr) == SYS_STATUS_READY)
            {
                appData.Tmr50msHandle = SYS_TMR_CallbackPeriodic(50, 0,
&Timer50ms_Callback);
                appData.Tmr1sHandle = SYS_TMR_CallbackPeriodic(100, 0, &Test_Callback);
            }
            else
                break;


            RONIN_COMMAND_PROC_Initialize();
        //    SYS_PRINT("Application startup ok!\r\n");
        //    CO_OD_RAM.writeAnalogueOutput16Bit[0] = 0;
            RONINCNC_Initialize();
            ESP_COMM_Initialize(0);
            appData.state = APP_STATE_WAIT_IP;


            break;
        }
        case APP_STATE_WAIT_IP:
            if (UDPCOMM_GetState() == UDPCOMM_READY)
            {
                appData.state = APP_STATE_WAITING_CAN_READY;
            }
            break;
        case APP_STATE_WAITING_CAN_READY:
            if (CANOPENAPP_CANopenReady())
            {
                SYS_CONSOLE_PRINT("Application ready...\r\n");
                appData.state = APP_STATE_SERVICE_TASKS;
            }
            break;
        case APP_STATE_SERVICE_TASKS:
        {
            RONINCNC_Tasks();
            ESP_COMM_Tasks();
            RONIN_COMMAND_PROC_Tasks();

            LedTask();
            //SYS_CMD_READY_TO_READ();

           // SYS_MESSAGE(appData.ConsoleBuf);
            break;
        }

        /* TODO: implement your application state machine.*/
```

```
        /* The default state should never be executed. */
        default:
        {
            /* TODO: Handle error in application's state machine. */
            break;
        }
    }
}


/*******************************************************************************
 End of File
 */
```

Fails "app.h"

```
/*******************************************************************************
  MPLAB Harmony Application Header File

  Company:
    Microchip Technology Inc.

  File Name:
    app.h

  Summary:
    This header file provides prototypes and definitions for the application.

  Description:
    This header file provides function prototypes and data type definitions for
    the application.  Some of these are required by the system (such as the
    "APP_Initialize" and "APP_Tasks" prototypes) and some of them are only used
    internally by the application (such as the "APP_STATES" definition).  Both
    are defined here for convenience.
*******************************************************************************/

//DOM-IGNORE-BEGIN
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 *******************************************************************************/
//DOM-IGNORE-END

#ifndef _APP_H
#define _APP_H

// *****************************************************************************
// *****************************************************************************
// Section: Included Files
// *****************************************************************************
// *****************************************************************************

#include <stdint.h>
#include <stdbool.h>
#include <stddef.h>
#include <stdlib.h>
#include "system_config.h"
#include "system_definitions.h"
#include "RONINCommandProc.h"
```

```
// DOM-IGNORE-BEGIN
#ifdef __cplusplus  // Provide C++ Compatibility

extern "C" {

#endif
// DOM-IGNORE-END

// *****************************************************************************
// *****************************************************************************
// Section: Type Definitions
// *****************************************************************************
// *****************************************************************************

#define USE_CAN 1

    // *****************************************************************************
/* Application states

  Summary:
    Application states enumeration

  Description:
    This enumeration defines the valid application states.  These states
    determine the behavior of the application at various times.
*/

typedef enum
{
      /* Application's state machine's initial state. */
      APP_STATE_INIT=0,
    APP_STATE_WAITING_CAN_READY,
    APP_STATE_WAIT_IP,
      APP_STATE_SERVICE_TASKS,


      /* TODO: Define states used by the application state machine. */

} APP_STATES;


// *****************************************************************************
/* Application Data

  Summary:
    Holds application data

  Description:
    This structure holds the application's data.

  Remarks:
    Application strings and buffers are be defined outside this structure.
 */

typedef struct
{
    /* The application's current state */
    APP_STATES state;

    /* TODO: Define any additional data used by the application. */

    SYS_TMR_HANDLE Tmr1sHandle;
    SYS_TMR_HANDLE Tmr50msHandle;
    uint8_t ConsoleBuf[100];
```

```
} APP_DATA;


// *****************************************************************************
// *****************************************************************************
// Section: Application Callback Routines
// *****************************************************************************
// *****************************************************************************
/* These routines are called by drivers when certain events occur.
*/

// *****************************************************************************
// *****************************************************************************
// Section: Application Initialization and State Machine Functions
// *****************************************************************************
// *****************************************************************************

/*******************************************************************************
  Function:
    void APP_Initialize ( void )

  Summary:
     MPLAB Harmony application initialization routine.

  Description:
    This function initializes the Harmony application.  It places the
    application in its initial state and prepares it to run so that its
    APP_Tasks function can be called.

  Precondition:
    All other system initialization routines should be called before calling
    this routine (in "SYS_Initialize").

  Parameters:
    None.

  Returns:
    None.

  Example:
    <code>
    APP_Initialize();
    </code>

  Remarks:
    This routine must be called from the SYS_Initialize function.
*/

void APP_Initialize ( void );


/*******************************************************************************
  Function:
    void APP_Tasks ( void )

  Summary:
    MPLAB Harmony Demo application tasks function

  Description:
    This routine is the Harmony Demo application's tasks function.  It
    defines the application's state machine and core logic.

  Precondition:
```

```
    The system and application initialization ("SYS_Initialize") should be
    called before calling this.

  Parameters:
    None.

  Returns:
    None.

  Example:
    <code>
    APP_Tasks();
    </code>

  Remarks:
    This routine must be called from SYS_Tasks() routine.
 */

void APP_Tasks( void );


#endif /* _APP_H */

//DOM-IGNORE-BEGIN
#ifdef __cplusplus
}
#endif
//DOM-IGNORE-END

/*******************************************************************************
 End of File
 */
```

Fails “CANopenApp.c”

```
/*******************************************************************************
  MPLAB Harmony Application Source File

  Company:
    Microchip Technology Inc.

  File Name:
    canopenapp.c

  Summary:
    This file contains the source code for the MPLAB Harmony application.

  Description:
    This file contains the source code for the MPLAB Harmony application.  It
    implements the logic of the application's state machine and it may call
    API routines of other MPLAB Harmony modules in the system, such as drivers,
    system services, and middleware.  However, it does not call any of the
    system interfaces (such as the "Initialize" and "Tasks" functions) of any of
    the modules in the system or make any assumptions about when those functions
    are called.  That is the responsibility of the configuration-specific system
    files.
 *******************************************************************************/

// DOM-IGNORE-BEGIN
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SUBSTITUTE GOODS, TECHNOLOGY, SERVICES, OR ANY CLAIMS BY THIRD PARTIES
(INCLUDING BUT NOT LIMITED TO ANY DEFENSE THEREOF), OR OTHER SIMILAR COSTS.
 *******************************************************************************/
// DOM-IGNORE-END//

 *****************************************************************************
// *****************************************************************************
// Section: Included Files
// *****************************************************************************
// *****************************************************************************

#include "canopenapp.h"
#include "UDPComm/PIC32_Harmony/udpcomm.h"



// *****************************************************************************
// *****************************************************************************
```

```
// Section: Global Data Definitions
// *****************************************************************************
// *****************************************************************************
#define CO_TMR_ISR_FLAG     IFS0bits.T2IF    /* Interrupt Flag bit */


typedef enum
{
    CANOPENAPP_TRANSFER_STATE_Init = 0,
    CANOPENAPP_TRANSFER_STATE_Idle,
    CANOPENAPP_TRANSFER_STATE_DownloadingObjects,
    CANOPENAPP_TRANSFER_STATE_UploadingObjects,
    CANOPENAPP_TRANSFER_STATE_Error
} CANOPENAPP_TRANSFER_STATE;

typedef struct
{
    CANOPENAPP_TRANSFER_STATE State;
    uint8_t TransferNodeID;
    CO_OBJECT *ObjectsToTransfer;
    CO_OBJECT *TransferBaseObject;
    int16_t TransferCount;


    CO_OBJECT *ObjectsToUpload;
    CO_OBJECT *UploadBase;
    int16_t UploadCount;
    CO_OBJECT *ObjectsToDownload;
    CO_OBJECT *DownloadBase;
    int16_t DownloadCount;
    CANOPENAPP_SDO_ClientOpeResult_t TransferResult;
    struct
    {
        uint32_t WaitComplete:1;
    } Flags;

} CANOPENAPP_TRANSFER_TAKS_DATA;


// *****************************************************************************
/* Application Data

  Summary:
    Holds application data

  Description:
    This structure holds the application's data.

  Remarks:
    This structure should be initialized by the APP_Initialize function.

    Application strings and buffers are be defined outside this structure.
*/

const CO_CANbitRateData_t  CO_CANbitRateData[8] = {CO_CANbitRateDataInitializers};
CANOPENAPP_DATA canopenappData;
CANOPENAPP_TRANSFER_TAKS_DATA _td;



void Tmr1ms_Callback ( uintptr_t context, uint32_t currTick );

// *****************************************************************************
// *****************************************************************************
```

```
// Section: Application Callback Functions
// *****************************************************************************
// *****************************************************************************

/* TODO:  Add any necessary callback functions.
*/

// *****************************************************************************
// *****************************************************************************
// Section: Application Local Functions
// *****************************************************************************
// *****************************************************************************

/* TODO:  Add any necessary local functions.
*/
#ifdef RONIN_CM_V1_4
void __ISR(_CAN1_VECTOR, ipl5AUTO) IntCAN1(void)
{
#if USE_CAN == 1
    Nop();
    Nop();
    Nop();

    CO_CANinterrupt(CO->CANmodule[0]);
    IFS4bits.CAN1IF = 0;
#endif
}
#endif
#ifdef RONIN_PIC32MZ_starter
void __ISR(_CAN1_VECTOR, ipl5AUTO) IntCAN1(void)
{
    Nop();
    Nop();
    Nop();

    CO_CANinterrupt(CO->CANmodule[0]);
    IFS4bits.CAN1IF = 0;
}
#endif
#ifdef RONIN_CM_B
void __ISR(_CAN1_VECTOR, ipl5AUTO) IntCAN1(void)
{
    Nop();
    Nop();
    Nop();

    CO_CANinterrupt(CO->CANmodule[0]);
    IFS4bits.CAN1IF = 0;
}
#endif



#ifdef RONIN_Explorer16
void __ISR(_CAN_1_VECTOR, ipl1AUTO) IntCAN1(void)
{
    Nop();
    Nop();
    Nop();

    CO_CANinterrupt(CO->CANmodule[0]);
    IFS1bits.CAN1IF = 0;
}
#endif
```

```
void Tmr1ms_Callback ( uintptr_t context, uint32_t currTick )
{
#if USE_CAN == 1
    CO_TMR_ISR_FLAG = 0;
    bool_t syncWas;
    canopenappData.CO_timer1ms++;

    if(CO->CANmodule[0]->CANnormal)
    {
        /* Process Sync */
        //syncWas = CO_process_SYNC(CO, 1000, NULL);
        syncWas = false;

        /* Read inputs */
        CO_process_RPDO(CO, syncWas);

        /* Further I/O or nonblocking application code may go here. */
#if CO_NO_TRACE > 0
        OD_time.epochTimeOffsetMs++;
        for(i=0; i<OD_traceEnable && i<CO_NO_TRACE; i++) {
            CO_trace_process(CO->trace[i], OD_time.epochTimeOffsetMs);
        }
#endif
        /* Write outputs */
        CO_process_TPDO(CO, syncWas, 1000, NULL);

        /* verify timer overflow */
        if(CO_TMR_ISR_FLAG == 1){
            CO_errorReport(CO->em, CO_EM_ISR_TIMER_OVERFLOW, CO_EMC_SOFTWARE_INTERNAL, 0);
            CO_TMR_ISR_FLAG = 0;
        }
    }
    /* calculate cycle time for performance measurement */
//    uint16_t t = CO_TMR_TMR / (CO_PBCLK / 100);
//    OD_performance[ODA_performance_timerCycleTime] = t;
//    if(t > OD_performance[ODA_performance_timerCycleMaxTime])
//        OD_performance[ODA_performance_timerCycleMaxTime] = t;
#endif
}

// *****************************************************************************
// *****************************************************************************
// Section: Application Initialization and State Machine Functions
// *****************************************************************************
// *****************************************************************************

/*******************************************************************************
  Function:
    void CANOPENAPP_Initialize ( void )

  Remarks:
    See prototype in canopenapp.h.
 */

void CANOPENAPP_Initialize ( void )
{
#if USE_CAN == 1

    /* Place the App state machine in its initial state. */
    canopenappData.state = CANOPENAPP_STATE_INIT;


    /* TODO: Initialize your application's state machine and other
     * parameters.
```

```
     */

    //C1MODEOff();        //Transciever mode - high speed

    canopenappData.CO_timer1ms = 0;
    canopenappData.timer1msDiff = 0;
    canopenappData.timer1msPrevious = 0;

    canopenappData.reset = CO_RESET_NOT;
    canopenappData.Flags.SDO_ClientUploadStarted = 0;
    canopenappData.Flags.SDO_ClientDownloadStarted = 0;

#ifdef RONIN_CM_V1_4
    IFS4bits.CAN1IF = 0;
    IPC37bits.CAN1IP = 5;
    IEC4bits.CAN1IE = 1;
#endif

#ifdef RONIN_PIC32MZ_starter
    IFS4bits.CAN1IF = 0;
    IPC37bits.CAN1IP = 5;
    IEC4bits.CAN1IE = 1;
#endif
#ifdef RONIN_CM_B
    IFS4bits.CAN1IF = 0;
    IPC37bits.CAN1IP = 5;
    IEC4bits.CAN1IE = 1;
#endif

#ifdef RONIN_Explorer16
    IFS1bits.CAN1IF = 0;
    IPC11bits.CAN1IP = 1;
    IEC1bits.CAN1IE = 1;
#endif

    //CAN tranceiver - high speed mode
    CAN_MODEOff();

    //CAN module address is given just 0 for CAN1 registers as driver
    //address calculation macro uses only CAN1
    /* Allocate memory */
    canopenappData.err = CO_new(&canopenappData.HeapMemoryUsed);
    if (canopenappData.err != CO_ERROR_NO) {
        while(1);
    }

    canopenappData.err = CO_CANinit((void *)_CAN1_BASE_ADDRESS, CANAAPP_BITRATE);

//    canopenappData.err = CO_init(
//            0/* CAN module address */,
//            9/* NodeID */,
//            CANAAPP_BITRATE /* bit rate */);

    canopenappData.err = CO_CANopenInit(9);     //TODO: How to get ID from configurator?



    canopenappData.reset = CO_RESET_NOT;
    canopenappData.timer1msPrevious = canopenappData.CO_timer1ms;
    canopenappData.DownloadResult = CANOPENAPP_SDO_ClientIdle;
    canopenappData.UploadResult = CANOPENAPP_SDO_ClientIdle;
#endif
}
```

```
CANOPENAPP_SDO_ClientOpeResult_t CANOPENAPP_TRANSFER_Initiate(uint8_t nodeID, CO_OBJECT
*objArr, uint16_t len, CANOPENAPP_SDO_TRANSFER_TYPE tType, bool waitComplete)
{
    CANOPENAPP_SDO_ClientOpeResult_t ret = CANOPENAPP_SDO_ClientBusy;
    if (!_td.TransferCount && _td.State == CANOPENAPP_TRANSFER_STATE_Idle)
    {
        _td.TransferNodeID = nodeID;
        _td.TransferBaseObject = objArr;
        _td.ObjectsToTransfer = objArr;
        _td.TransferCount = len;
        _td.Flags.WaitComplete = waitComplete ? 1 : 0;
        _td.TransferResult = CANOPENAPP_SDO_ClientBusy;
        switch(tType)
        {
            case CANOPENAPP_SDO_TRANSFER_UPLOAD:
                _td.State = CANOPENAPP_TRANSFER_STATE_UploadingObjects;
                break;
            case CANOPENAPP_SDO_TRANSFER_DOWNLOAD:
                _td.State = CANOPENAPP_TRANSFER_STATE_DownloadingObjects;
                break;
            default:
                break;
        }
        ret = CANOPENAPP_SDO_ClientOpeScheduled;
    }


    return ret;
}

bool CANOPENAPP_CANopenReady(void)
{
    bool ret = false;
    if (_td.State > CANOPENAPP_TRANSFER_STATE_Init &&
            canopenappData.state == CANOPENAPP_STATE_SERVICE_TASKS)
        ret = true;
    return ret;
}

CANOPENAPP_SDO_ClientOpeResult_t CANOPENAPP_TRANSFER_Result(CO_OBJECT *transferBaseObj)
{
    CANOPENAPP_SDO_ClientOpeResult_t ret = CANOPENAPP_SDO_ClientBusy;
    /* Check if completion status request is about the same object array
     for which transfer was initiated, if not, show that busy */
    if (transferBaseObj == _td.TransferBaseObject || _td.State ==
CANOPENAPP_TRANSFER_STATE_Idle)
    {
        ret = _td.TransferResult;
        if (_td.TransferCount == 0)
        {
            _td.State = CANOPENAPP_TRANSFER_STATE_Idle;
        }
    }
    return ret;
}


/*
 * Handles data bulk transfer using SDO.
 * Called periodically in CANOPENAPP_Tasks
 */
void CANOPENAPP_DataTransferTasks(void)
{
```

```
    CANOPENAPP_SDO_ClientOpeResult_t res;
    switch(_td.State)
    {
        case CANOPENAPP_TRANSFER_STATE_Init:
            _td.TransferCount = 0;
            _td.State = CANOPENAPP_TRANSFER_STATE_Idle;
            break;
        case CANOPENAPP_TRANSFER_STATE_Idle:
            _td.TransferResult = CANOPENAPP_SDO_ClientIdle;
            break;
        case CANOPENAPP_TRANSFER_STATE_DownloadingObjects:
            res = SDO_ClientDownload(
                                    _td.TransferNodeID,
                                    _td.ObjectsToTransfer->Idx,
                                    _td.ObjectsToTransfer->SubIdx,
                                    (uint8_t*)&_td.ObjectsToTransfer->Value,
                                    _td.ObjectsToTransfer->Size,
                                    NULL);
            switch(res)
            {
                case CANOPENAPP_SDO_ClientOpeResultOK:
                    _td.TransferCount--;
                    if (_td.TransferCount)
                        _td.ObjectsToTransfer++;
                    else
                    {
                        _td.TransferResult = CANOPENAPP_SDO_ClientOpeResultOK;
                        if (!_td.Flags.WaitComplete) _td.State =
CANOPENAPP_TRANSFER_STATE_Idle;
                    }
                    break;
                case CANOPENAPP_SDO_ClientCANerror:
                case CANOPENAPP_SDO_ClientArgError:
                    _td.TransferCount = 0;
                    _td.TransferResult = CANOPENAPP_SDO_ClientCANerror;
                    if (!_td.Flags.WaitComplete) _td.State =
CANOPENAPP_TRANSFER_STATE_Idle;
                    break;
                default:
                    break;
            }
            break;
        case CANOPENAPP_TRANSFER_STATE_UploadingObjects:
            if (_td.TransferCount)
            {
                res = SDO_ClientUpload( _td.TransferNodeID,
                                        _td.ObjectsToTransfer->Idx,
                                        _td.ObjectsToTransfer->SubIdx,
                                        &_td.ObjectsToTransfer->Value,
                                        NULL);
                switch(res)
                {
                    case CANOPENAPP_SDO_ClientOpeResultOK:
                        SYS_CONSOLE_PRINT("CAN%x(%x)\t%x\r\n",
                                        _td.ObjectsToTransfer->Idx,
                                        _td.ObjectsToTransfer->SubIdx,
                                        _td.ObjectsToTransfer->Value);
                        _td.TransferCount--;
                        if (_td.TransferCount)
                            _td.ObjectsToTransfer++;
                        else
                        {
                            _td.TransferResult = CANOPENAPP_SDO_ClientOpeResultOK;
```

```
                            if (!_td.Flags.WaitComplete) _td.State =
CANOPENAPP_TRANSFER_STATE_Idle;
                        }
                        break;
                    case CANOPENAPP_SDO_ClientCANerror:
                    case CANOPENAPP_SDO_ClientArgError:
                        _td.TransferCount = 0;
                        _td.TransferResult = CANOPENAPP_SDO_ClientCANerror;
                        if (!_td.Flags.WaitComplete) _td.State =
CANOPENAPP_TRANSFER_STATE_Idle;
                        break;
                    default:
                        break;
                }
            }
            break;
        case CANOPENAPP_TRANSFER_STATE_Error:
            SYS_CONSOLE_PRINT("CAN open data transfer error\n\r");
            _td.State = CANOPENAPP_TRANSFER_STATE_Init;
            break;
        default:
            break;
    }
}

/******************************************************************************
  Function:
    void CANOPENAPP_Tasks ( void )

  Remarks:
    See prototype in canopenapp.h.
 */

void CANOPENAPP_Tasks ( void )
{
    static uint8_t rxBuff[55], tmptmr = 0;
    static CO_SDOclient_return_t sdoClient_ret;
    CO_SDOclient_return_t ret = 100;
    size_t sizeIndicated = 0, sizeTransferred = 0;
    CO_SDO_abortCode_t sdoAbortCode;

#if USE_CAN == 1
    if (canopenappData.CO_timer1ms >= canopenappData.timer1msPrevious)
    {
        canopenappData.timer1msDiff =
                canopenappData.CO_timer1ms - canopenappData.timer1msPrevious;
    }
    else
    {
        canopenappData.timer1msDiff =
                canopenappData.timer1msPrevious - canopenappData.CO_timer1ms
                + 0xFFFFFFFF;
    }
    canopenappData.timer1msPrevious = canopenappData.CO_timer1ms;
    tmptmr += canopenappData.timer1msDiff;

    /* Check the application's current state. */
    switch ( canopenappData.state )
    {
        /* Application's initial state. */
        case CANOPENAPP_STATE_INIT:
        {
            bool appInitialized = false;
```

```
            if (SYS_TMR_Status(sysObj.sysTmr) == SYS_STATUS_READY && (UDPCOMM_GetState()
== UDPCOMM_READY))
            {
                canopenappData.Tmr1msHandle = SYS_TMR_CallbackPeriodic(1, 0,
&Tmr1ms_Callback);
                appInitialized = true;
            }
            if (appInitialized)
            {
                /* start CAN */
                CO_CANsetNormalMode(CO->CANmodule[0]);

                canopenappData.netBootupTimer = 0;
                CO_NMT_sendCommand(CO->NMT, CO_NMT_RESET_COMMUNICATION, 0); //Adress all
nodes
                canopenappData.state = CANOPENAPP_STATE_RESETTING_NODES;
            }
            break;
        }
        case CANOPENAPP_STATE_RESETTING_NODES:

            canopenappData.netBootupTimer += canopenappData.timer1msDiff;
            if (canopenappData.netBootupTimer >= 5)
            {
                canopenappData.netBootupTimer = 0;
                CO_NMT_sendCommand(CO->NMT, CO_NMT_ENTER_OPERATIONAL, 0); //Adress all
nodes
                canopenappData.state = CANOPENAPP_STATE_STARTING_NODES;
            }
            break;
        case CANOPENAPP_STATE_STARTING_NODES:
            canopenappData.netBootupTimer += canopenappData.timer1msDiff;
            if (canopenappData.netBootupTimer >= 10)
            {
                canopenappData.state = CANOPENAPP_STATE_SETTING_UP_NODES;
            }
            break;
        case CANOPENAPP_STATE_SETTING_UP_NODES:

            CO->NMT->resetCommand = 0;      //TODO: Workaround, because was set and not
unset somewhere
                                            //as a result constantly resets CAN





            canopenappData.state = CANOPENAPP_STATE_SERVICE_TASKS;

            break;
        case CANOPENAPP_STATE_SERVICE_TASKS:
        {
            canopenappData.reset = CO_RESET_NOT;
            if (CO_OD_RAM.errorStatusBits[0] != 0) CO_OD_RAM.errorStatusBits[0] = 0;
//TODO: Workaround
            if (CO_OD_RAM.errorStatusBits[2] != 0) CO_OD_RAM.errorStatusBits[2] = 0;
            if (CO_OD_RAM.errorStatusBits[3] != 0) CO_OD_RAM.errorStatusBits[3] = 0;

            /* CANopen process */
            canopenappData.reset = CO_process(CO, canopenappData.timer1msDiff * 1000,
NULL);
            if (canopenappData.reset != CO_RESET_NOT)
                canopenappData.state = CANOPENAPP_STATE_ERROR;
```

```
            if (CO->NMT->operatingState != CO_NMT_OPERATIONAL)
                canopenappData.state = CANOPENAPP_STATE_ERROR;

            CANOPENAPP_DataTransferTasks();


            /*
             * SDO client upload process
             */
            switch(canopenappData.UploadResult)
            {
                case CANOPENAPP_SDO_ClientOpeScheduled:
                    ret = CO_SDOclientUpload(
                                            CO->SDOclient[0],
                                            canopenappData.timer1msDiff * 1000,
                                            &sdoAbortCode,
                                            &sizeIndicated, &sizeTransferred, NULL);
                    if (ret <= CO_SDOcli_ok_communicationEnd)
                    {
                        if (ret == CO_SDOcli_ok_communicationEnd)
                        {
                            CO_SDOclientUploadBufRead(
                                    CO->SDOclient[0],
                                    canopenappData.SDO_ClientUploadBuff,
                                    sizeTransferred);
                            canopenappData.UploadResult =
CANOPENAPP_SDO_ClientOpeResultOK;
                        }
                        else
                            canopenappData.UploadResult = CANOPENAPP_SDO_ClientCANerror;
                        CO_SDOclientClose(CO->SDOclient[0]);
                    }
                    break;
                default:
                    break;
            }

            /*
             * SDO client download process
             */
            switch(canopenappData.DownloadResult)
            {
                case CANOPENAPP_SDO_ClientOpeScheduled:
                    ret = CO_SDOclientDownload(
                                            CO->SDOclient[0],
                                            canopenappData.timer1msDiff * 1000,
                                            false,
                                            &sdoAbortCode,
                                            &sizeTransferred, NULL);
                    if (ret <= CO_SDOcli_ok_communicationEnd)
                    {
                        if (ret == CO_SDOcli_ok_communicationEnd)
                            canopenappData.DownloadResult =
CANOPENAPP_SDO_ClientOpeResultOK;
                        else
                            canopenappData.DownloadResult = CANOPENAPP_SDO_ClientCANerror;
                        CO_SDOclientClose(CO->SDOclient[0]);
                    }
                    break;
                default:
                    break;
            }
            break;
```

```
        }
        case CANOPENAPP_STATE_ERROR:
            canopenappData.netBootupTimer = 0;
            CO_NMT_sendCommand(CO->NMT, CO_NMT_RESET_COMMUNICATION, 0);
            canopenappData.state = CANOPENAPP_STATE_RESETTING_NODES;
            break;

        /* TODO: implement your application state machine.*/


        /* The default state should never be executed. */
        default:
        {
            /* TODO: Handle error in application's state machine. */
            break;
        }
    }
#endif
}


CANOPENAPP_SDO_ClientOpeResult_t CANOPENAPP_ReadPDOparameters(uint8_t nodeID, uint16_t
startIdx, uint16_t PDOparamCount, uint32_t *buff)
{
    static uint8_t subidx = 0;
    static uint32_t objectCount = 0;
    static uint16_t curridx = 0;
    static uint8_t phase = 0;
    static uint32_t bufIdx;
    CANOPENAPP_SDO_ClientOpeResult_t ret = CANOPENAPP_SDO_ClientBusy;
    if (curridx == 0)
    {
        curridx = startIdx;
        bufIdx = 0;
        subidx = 0;
        objectCount = 0;
        phase = 0;
    }
    ret = SDO_ClientUpload(1, curridx, subidx, buff + bufIdx, NULL);
    switch(ret)
    {
        case CANOPENAPP_SDO_ClientOpeResultOK:
            ret = CANOPENAPP_SDO_ClientOpeScheduled;
            if (subidx == 0)
                objectCount = buff[bufIdx] + 1; //Max subindex + 1
            bufIdx++;
            subidx++;
            phase = 0;
            if (subidx == objectCount)
            {
                objectCount = 0;
                subidx = 0;
                curridx++;
                if (curridx == PDOparamCount + startIdx)
                {
                    ret = CANOPENAPP_SDO_ClientOpeResultOK;
                    curridx = 0;
                }
            }
            break;
        case CANOPENAPP_SDO_ClientOpeScheduled:
            phase = 1;
            break;
        case CANOPENAPP_SDO_ClientBusy:
```

```
            break;
        case CANOPENAPP_SDO_ClientCANerror:
        case CANOPENAPP_SDO_ClientArgError:
            ret = CANOPENAPP_SDO_ClientCANerror;
        default: break;
    }

    return ret;
}


CANOPENAPP_SDO_ClientOpeResult_t SDO_ClientUpload(  uint8_t nodeID,
                                                    uint16_t idx,
                                                    uint8_t subidx,
                                                    uint8_t *dataRx,
                                                    CANOPENAPP_SDO_CLIENT_CALLBACK
callback)
{
    CO_SDOclient_return_t ret = CO_SDOcli_ok_communicationEnd;
    CANOPENAPP_SDO_ClientOpeResult_t result = CANOPENAPP_SDO_ClientBusy;
    CO_SDOclient_t *SDOclient = CO->SDOclient[0];
    switch(canopenappData.UploadResult)
    {
        case CANOPENAPP_SDO_ClientIdle:
            canopenappData.SDO_ClientUploadBuff = dataRx;
            /* Setup client. */
            ret = CO_SDOclient_setup(  SDOclient, 0, 0, nodeID);
            if(ret == CO_SDOcli_ok_communicationEnd)
            {
                /* Initiate upload. */
                ret = CO_SDOclientUploadInitiate(
                                    SDOclient, idx, subidx,
                                    CO_SDO_SERVER_TIMEOUT,
                                    CO_SDO_BLOCK_TRANSFER_ENABLE);
                if (ret == CO_SDOcli_ok_communicationEnd)
                {
                    result = canopenappData.UploadResult =
CANOPENAPP_SDO_ClientOpeScheduled;
                    break;
                }
            }
            result = CANOPENAPP_SDO_ClientCANerror;
            break;
        case CANOPENAPP_SDO_ClientOpeResultOK:
        case CANOPENAPP_SDO_ClientCANerror:
        case CANOPENAPP_SDO_ClientArgError:
            result = canopenappData.UploadResult;
            canopenappData.UploadResult = CANOPENAPP_SDO_ClientIdle;
        default:
            break;
    }
    return result;
}

CANOPENAPP_SDO_ClientOpeResult_t SDO_ClientDownload(  uint8_t nodeID,
                                                    uint16_t idx,
                                                    uint8_t subidx,
                                                    uint8_t *dataTx,
                                                    size_t txSize,
                                                    CANOPENAPP_SDO_CLIENT_CALLBACK
callback)
{
    CO_SDOclient_return_t ret = CO_SDOcli_ok_communicationEnd;
    CANOPENAPP_SDO_ClientOpeResult_t result = CANOPENAPP_SDO_ClientBusy;
```

```
    CO_SDOclient_t *SDOclient = CO->SDOclient[0];
    switch(canopenappData.DownloadResult)
    {
        case CANOPENAPP_SDO_ClientIdle:
            canopenappData.DownloadSize = txSize;
            canopenappData.SDO_ClientDownloadBuff = dataTx;

            /* Setup client. */
            ret = CO_SDOclient_setup(  SDOclient, 0, 0, nodeID);
            if(ret == CO_SDOcli_ok_communicationEnd)
            {
                /* Initiate download. */
                ret = CO_SDOclientDownloadInitiate(
                                    SDOclient, idx, subidx,
                                    txSize,
                                    CO_SDO_SERVER_TIMEOUT,
                                    CO_SDO_BLOCK_TRANSFER_ENABLE);
                if (ret == CO_SDOcli_ok_communicationEnd)
                {
                    /* Write data to SDO buffer */
                    if (txSize == CO_SDOclientDownloadBufWrite( SDOclient, dataTx, txSize
))
                    {
                        result = canopenappData.DownloadResult =
CANOPENAPP_SDO_ClientOpeScheduled;
                        break;
                    }
                }
            }
            result = CANOPENAPP_SDO_ClientCANerror;
            break;
        case CANOPENAPP_SDO_ClientOpeResultOK:
        case CANOPENAPP_SDO_ClientCANerror:
        case CANOPENAPP_SDO_ClientArgError:
            result = canopenappData.DownloadResult;
            canopenappData.DownloadResult = CANOPENAPP_SDO_ClientIdle;
        default:
            break;
    }
    return result;
}


/*******************************************************************************
 End of File
 */
```

Fails "CANopenApp.h"

```
/*******************************************************************************
  MPLAB Harmony Application Header File

  Company:
    Microchip Technology Inc.

  File Name:
    canopenapp.h

  Summary:
    This header file provides prototypes and definitions for the application.

  Description:
    This header file provides function prototypes and data type definitions for
    the application.  Some of these are required by the system (such as the
    "APP_Initialize" and "APP_Tasks" prototypes) and some of them are only used
    internally by the application (such as the "APP_STATES" definition).  Both
    are defined here for convenience.
*******************************************************************************/

//DOM-IGNORE-BEGIN
/*******************************************************************************
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SUBSTITUTE GOODS, TECHNOLOGY, SERVICES, OR ANY CLAIMS BY THIRD PARTIES
(INCLUDING BUT NOT LIMITED TO ANY DEFENSE THEREOF), OR OTHER SIMILAR COSTS.
 *******************************************************************************/
//DOM-IGNORE-END

#ifndef _APP_H
#define _APP_H

// *****************************************************************************
// *****************************************************************************
// Section: Included Files
// *****************************************************************************
// *****************************************************************************

#include <stdint.h>
#include <stdbool.h>
#include <stddef.h>
#include <stdlib.h>
#include "system_config.h"
#include "system_definitions.h"
#include "RONINCommandProc.h"
```

```
// DOM-IGNORE-BEGIN
#ifdef __cplusplus  // Provide C++ Compatibility

extern "C" {

#endif
// DOM-IGNORE-END

// *****************************************************************************
// *****************************************************************************
// Section: Type Definitions
// *****************************************************************************
// *****************************************************************************

#define USE_CAN 1

    // *****************************************************************************
/* Application states

  Summary:
    Application states enumeration

  Description:
    This enumeration defines the valid application states.  These states
    determine the behavior of the application at various times.
*/

typedef enum
{
      /* Application's state machine's initial state. */
      APP_STATE_INIT=0,
    APP_STATE_WAITING_CAN_READY,
    APP_STATE_WAIT_IP,
      APP_STATE_SERVICE_TASKS,


      /* TODO: Define states used by the application state machine. */

} APP_STATES;


// *****************************************************************************
/* Application Data

  Summary:
    Holds application data

  Description:
    This structure holds the application's data.

  Remarks:
    Application strings and buffers are be defined outside this structure.
 */

typedef struct
{
    /* The application's current state */
    APP_STATES state;

    /* TODO: Define any additional data used by the application. */

    SYS_TMR_HANDLE Tmr1sHandle;
    SYS_TMR_HANDLE Tmr50msHandle;
    uint8_t ConsoleBuf[100];
```

```
} APP_DATA;


// *****************************************************************************
// *****************************************************************************
// Section: Application Callback Routines
// *****************************************************************************
// *****************************************************************************
/* These routines are called by drivers when certain events occur.
*/

// *****************************************************************************
// *****************************************************************************
// Section: Application Initialization and State Machine Functions
// *****************************************************************************
// *****************************************************************************

/*******************************************************************************
  Function:
    void APP_Initialize ( void )

  Summary:
     MPLAB Harmony application initialization routine.

  Description:
    This function initializes the Harmony application.  It places the
    application in its initial state and prepares it to run so that its
    APP_Tasks function can be called.

  Precondition:
    All other system initialization routines should be called before calling
    this routine (in "SYS_Initialize").

  Parameters:
    None.

  Returns:
    None.

  Example:
    <code>
    APP_Initialize();
    </code>

  Remarks:
    This routine must be called from the SYS_Initialize function.
*/

void APP_Initialize ( void );


/*******************************************************************************
  Function:
    void APP_Tasks ( void )

  Summary:
    MPLAB Harmony Demo application tasks function

  Description:
    This routine is the Harmony Demo application's tasks function.  It
    defines the application's state machine and core logic.

  Precondition:
```

```
    The system and application initialization ("SYS_Initialize") should be
    called before calling this.

  Parameters:
    None.

  Returns:
    None.

  Example:
    <code>
    APP_Tasks();
    </code>

  Remarks:
    This routine must be called from SYS_Tasks() routine.
 */

void APP_Tasks( void );


#endif /* _APP_H */

//DOM-IGNORE-BEGIN
#ifdef __cplusplus
}
#endif
//DOM-IGNORE-END

/*******************************************************************************
 End of File
 */
```

20. Pielikums

Fails "CO_config.h"

```
/**
 * Configuration macros for CANopenNode.
 *
 * @file        CO_config.h
 * @ingroup     CO_driver
 * @author      Janez Paternoster
 * @copyright   2020 Janez Paternoster
 *
 * This file is part of CANopenNode, an opensource CANopen Stack.
 * Project home page is <https://github.com/CANopenNode/CANopenNode>.
 * For more information on CANopen see <http://www.can-cia.org/>.
 *
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 * WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied.
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 * limitations under the License.
 */


#ifndef CO_CONFIG_FLAGS_H
#define CO_CONFIG_FLAGS_H

#ifdef __cplusplus
extern "C" {
#endif

/**
 * @defgroup CO_STACK_CONFIG Stack configuration
 * @ingroup CO_driver
 *
 * Stack configuration macros specify, which parts of the stack will be enabled.
 *
 * Default values for stack configuration macros are set in CO_driver.h file.
 * They can be overridden by CO_driver_target.h file. If specified so, they can
 * further be overridden by CO_driver_custom.h file.
 *
 * Stack configuration macro is specified as bits, where each bit
 * enables/disables some part of the configurable CANopenNode object. Flags are
 * used for enabling or checking specific bit. Multiple flags can be ORed
 * together.
 *
 * Configuration macros may be in relation with @ref CO_NO_OBJ macros from
 * CANopen.h file. Former enables/disables stack functionalities, latter
 * enables/disables objects in object dictionary. Note that some objects in
 * object dictionary may need some configuration macros to be enabled.
 * @{
 */


/**
 * Enable custom callback after CAN receive
 *
 * Flag enables optional callback functions, which are part of some CANopenNode
 * objects. Callbacks can optionally be registered by application, which
 * configures threads in operating system. Callbacks are called after something
```

```
 * has been preprocessed by higher priority thread and must be further
 * processed by lower priority thread. For example when CAN message is received
 * and preprocessed, callback should wake up mainline processing function.
 * See also @ref CO_process() function.
 *
 * If callback functions are used, they must be initialized separately, after
 * the object initialization.
 *
 * This flag is common to multiple configuration macros.
 */
#define CO_CONFIG_FLAG_CALLBACK_PRE 0x1000


/**
 * Enable calculation of timerNext_us variable.
 *
 * Calculation of the timerNext_us variable is useful for smooth operation on
 * operating system. See also @ref CO_process() function.
 *
 * This flag is common to multiple configuration macros.
 */
#define CO_CONFIG_FLAG_TIMERNEXT 0x2000


/**
 * Configuration of NMT_Heartbeat object
 *
 * Possible flags, can be ORed:
 * - #CO_CONFIG_FLAG_CALLBACK_PRE - Enable custom callback after preprocessing
 *   received NMT CAN message.
 *   Callback is configured by CO_NMT_initCallbackPre().
 * - #CO_CONFIG_FLAG_TIMERNEXT - Enable calculation of timerNext_us variable
 *   inside CO_NMT_process().
 * - CO_CONFIG_NMT_CALLBACK_CHANGE - Enable custom callback after NMT
 *   state changes. Callback is configured by
 *   CO_NMT_initCallbackChanged().
 * - CO_CONFIG_NMT_MASTER - Enable simple NMT master
 */
#ifdef CO_DOXYGEN
#define CO_CONFIG_NMT (CO_CONFIG_FLAG_CALLBACK_PRE | CO_CONFIG_FLAG_TIMERNEXT |
CO_CONFIG_NMT_CALLBACK_CHANGE | CO_CONFIG_NMT_MASTER0)
#endif
#define CO_CONFIG_NMT_CALLBACK_CHANGE 0x01
#define CO_CONFIG_NMT_MASTER 0x02


/**
 * Configuration of SDO server object
 *
 * Possible flags, can be ORed:
 * - #CO_CONFIG_FLAG_CALLBACK_PRE - Enable custom callback after preprocessing
 *   received SDO CAN message.
 *   Callback is configured by CO_SDO_initCallbackPre().
 * - #CO_CONFIG_FLAG_TIMERNEXT - Enable calculation of timerNext_us variable
 *   inside CO_SDO_process().
 * - CO_CONFIG_SDO_SEGMENTED - Enable SDO server segmented transfer.
 * - CO_CONFIG_SDO_BLOCK - Enable SDO server block transfer. If set, then
 *   CO_CONFIG_SDO_SEGMENTED must also be set.
 */
#ifdef CO_DOXYGEN
#define CO_CONFIG_SDO (CO_CONFIG_FLAG_CALLBACK_PRE | CO_CONFIG_FLAG_TIMERNEXT |
CO_CONFIG_SDO_SEGMENTED | CO_CONFIG_SDO_BLOCK)
#endif
/* TODO with new OD */
```

```
#define CO_CONFIG_SDO_SEGMENTED 0x01
#define CO_CONFIG_SDO_BLOCK 0x02


/**
 * Size of the internal data buffer for the SDO server.
 *
 * Size must be at least equal to size of largest variable in
 * @ref CO_SDO_objectDictionary. If data type is domain, data length is not
 * limited to SDO buffer size. If block transfer is implemented, value should be
 * set to 889.
 *
 * Value can be in range from 7 to 889 bytes.
 */
#ifdef CO_DOXYGEN
#define CO_CONFIG_SDO_BUFFER_SIZE 32
#endif


/**
 * Configuration of Emergency object
 *
 * Possible flags, can be ORed:
 * - #CO_CONFIG_FLAG_CALLBACK_PRE - Enable custom callback after preprocessing
 *   emergency condition by CO_errorReport() or CO_errorReset() call.
 *   Callback is configured by CO_EM_initCallbackPre().
 * - #CO_CONFIG_FLAG_TIMERNEXT - Enable calculation of timerNext_us variable
 *   inside CO_EM_process().
 * - CO_CONFIG_EM_CONSUMER - Enable emergency consumer.
 */
#ifdef CO_DOXYGEN
#define CO_CONFIG_EM (CO_CONFIG_FLAG_CALLBACK_PRE | CO_CONFIG_FLAG_TIMERNEXT |
CO_CONFIG_EM_CONSUMER)
#endif
#define CO_CONFIG_EM_CONSUMER 0x01


/**
 * Configuration of Heartbeat Consumer
 *
 * Possible flags, can be ORed:
 * - #CO_CONFIG_FLAG_CALLBACK_PRE - Enable custom callback after preprocessing
 *   received heartbeat CAN message.
 *   Callback is configured by CO_HBconsumer_initCallbackPre().
 * - #CO_CONFIG_FLAG_TIMERNEXT - Enable calculation of timerNext_us variable
 *   inside CO_HBconsumer_process().
 * - CO_CONFIG_HB_CONS_CALLBACK_CHANGE - Enable custom callback after NMT
 *   state of the monitored node changes. Callback is configured by
 *   CO_HBconsumer_initCallbackNmtChanged().
 * - CO_CONFIG_HB_CONS_CALLBACK_MULTI - Enable multiple custom callbacks, which
 *   can be configured for each monitored node. Callback are configured by
 *   CO_HBconsumer_initCallbackHeartbeatStarted(),
 *   CO_HBconsumer_initCallbackTimeout() and
 *   CO_HBconsumer_initCallbackRemoteReset() functions.
 * - CO_CONFIG_HB_CONS_QUERY_FUNCT - Enable functions for query HB state or
 *   NMT state of the specific monitored node.
 */
#ifdef CO_DOXYGEN
#define CO_CONFIG_HB_CONS (CO_CONFIG_FLAG_CALLBACK_PRE | CO_CONFIG_FLAG_TIMERNEXT |
CO_CONFIG_HB_CONS_CALLBACK_CHANGE | CO_CONFIG_HB_CONS_CALLBACK_MULTI |
CO_CONFIG_HB_CONS_QUERY_FUNCT)
#endif
#define CO_CONFIG_HB_CONS_CALLBACK_CHANGE 0x01
#define CO_CONFIG_HB_CONS_CALLBACK_MULTI 0x02
```

```
#define CO_CONFIG_HB_CONS_QUERY_FUNCT 0x04

/**
 * Configuration of GFC
 *
 * Possible flags, can be ORed:
 * - CO_CONFIG_GFC_CONSUMER - Enable the GFC consumer
 * - CO_CONFIG_GFC_PRODUCER - Enable the GFC producer
 */
#ifdef CO_DOXYGEN
#define CO_CONFIG_GFC (CO_CONFIG_GFC_CONSUMER | CO_CONFIG_GFC_PRODUCER)
#endif
#define CO_CONFIG_GFC_CONSUMER 0x00
#define CO_CONFIG_GFC_PRODUCER 0x00

/**
 * Configuration of SRDO
 *
 * Possible flags, can be ORed:
 * - #CO_CONFIG_FLAG_CALLBACK_PRE - Enable custom callback after preprocessing
 *   received RSRDO CAN message.
 *   Callback is configured by CO_SRDO_initCallbackPre().
 * - #CO_CONFIG_FLAG_TIMERNEXT - Enable calculation of timerNext_us variable
 *   inside CO_SRDO_process() (Tx SRDO only).
 * - CO_CONFIG_RSRDO_CALLS_EXTENSION - Enable calling configured extension
 *   callbacks when received RSRDO CAN message modifies OD entries.
 * - CO_CONFIG_TRSRDO_CALLS_EXTENSION - Enable calling configured extension
 *   callbacks before TSRDO CAN message is sent.
 */
#ifdef CO_DOXYGEN
#define CO_CONFIG_SRDO (CO_CONFIG_FLAG_CALLBACK_PRE | CO_CONFIG_FLAG_TIMERNEXT |
CO_CONFIG_SRDO_CHECK_TX | CO_CONFIG_RSRDO_CALLS_EXTENSION |
CO_CONFIG_TSRDO_CALLS_EXTENSION)
#endif
#define CO_CONFIG_SRDO_CHECK_TX 0x0
#define CO_CONFIG_RSRDO_CALLS_EXTENSION 0x02
#define CO_CONFIG_TSRDO_CALLS_EXTENSION 0x04

/**
 * SRDO Tx time delay
 *
 * minimum time between the first and second SRDO (Tx) message
 * in us
 */
#ifdef CO_DOXYGEN
#define CO_CONFIG_SRDO_MINIMUM_DELAY 0
#endif

/**
 * Configuration of PDO
 *
 * Possible flags, can be ORed:
 * - #CO_CONFIG_FLAG_CALLBACK_PRE - Enable custom callback after preprocessing
 *   received RPDO CAN message.
 *   Callback is configured by CO_RPDO_initCallbackPre().
 * - #CO_CONFIG_FLAG_TIMERNEXT - Enable calculation of timerNext_us variable
 *   inside CO_TPDO_process().
 * - CO_CONFIG_PDO_SYNC_ENABLE - Enable SYNC object inside PDO objects.
 * - CO_CONFIG_RPDO_CALLS_EXTENSION - Enable calling configured extension
 *   callbacks when received RPDO CAN message modifies OD entries.
 * - CO_CONFIG_TPDO_CALLS_EXTENSION - Enable calling configured extension
 *   callbacks before TPDO CAN message is sent.
 */
#ifdef CO_DOXYGEN
```

```
#define CO_CONFIG_PDO (CO_CONFIG_FLAG_CALLBACK_PRE | CO_CONFIG_FLAG_TIMERNEXT |
CO_CONFIG_PDO_SYNC_ENABLE | CO_CONFIG_RPDO_CALLS_EXTENSION |
CO_CONFIG_TPDO_CALLS_EXTENSION)
#endif
#define CO_CONFIG_PDO_SYNC_ENABLE 0x00
#define CO_CONFIG_RPDO_CALLS_EXTENSION 0x02
#define CO_CONFIG_TPDO_CALLS_EXTENSION 0x04


/**
 * Configuration of SYNC
 *
 * Possible flags, can be ORed:
 * - #CO_CONFIG_FLAG_CALLBACK_PRE - Enable custom callback after preprocessing
 *   received SYNC CAN message.
 *   Callback is configured by CO_SYNC_initCallbackPre().
 * - #CO_CONFIG_FLAG_TIMERNEXT - Enable calculation of timerNext_us variable
 *   inside CO_SYNC_process().
 */
#ifdef CO_DOXYGEN
#define CO_CONFIG_SYNC (CO_CONFIG_FLAG_CALLBACK_PRE | CO_CONFIG_FLAG_TIMERNEXT)
#endif


/**
 * Configuration of SDO client object
 *
 * Possible flags, can be ORed:
 * - #CO_CONFIG_FLAG_CALLBACK_PRE - Enable custom callback after preprocessing
 *   received SDO CAN message.
 *   Callback is configured by CO_SDOclient_initCallbackPre().
 * - #CO_CONFIG_FLAG_TIMERNEXT - Enable calculation of timerNext_us variable
 *   inside CO_SDOclientDownloadInitiate(), CO_SDOclientDownload(),
 *   CO_SDOclientUploadInitiate(), CO_SDOclientUpload().
 * - CO_CONFIG_SDO_CLI_SEGMENTED - Enable SDO client segmented transfer.
 * - CO_CONFIG_SDO_CLI_BLOCK - Enable SDO client block transfer. If set, then
 *   CO_CONFIG_SDO_CLI_SEGMENTED must also be set.
 * - CO_CONFIG_SDO_CLI_LOCAL - Enable local transfer, if Node-ID of the SDO
 *   server is the same as node-ID of the SDO client. (SDO client is the same
 *   device as SDO server.) Transfer data directly without communication on CAN.
 */
#ifdef CO_DOXYGEN
#define CO_CONFIG_SDO_CLI (CO_CONFIG_FLAG_CALLBACK_PRE | CO_CONFIG_FLAG_TIMERNEXT |
CO_CONFIG_SDO_CLI_SEGMENTED | CO_CONFIG_SDO_CLI_BLOCK | CO_CONFIG_SDO_CLI_LOCAL)
#endif
#define CO_CONFIG_SDO_CLI_SEGMENTED 0x01
#define CO_CONFIG_SDO_CLI_BLOCK 0x02
#define CO_CONFIG_SDO_CLI_LOCAL 0x04
#define CO_CONFIG_SDO_CLI (CO_CONFIG_SDO_CLI_SEGMENTED |  CO_CONFIG_SDO_CLI_BLOCK |
CO_CONFIG_SDO_CLI_LOCAL)

/**
 * Size of the internal data buffer for the SDO client.
 *
 * Circular buffer is used for SDO communication. it can be read or written
 * between successive SDO calls. So size of the buffer can be lower than size of
 * the actual size of data transferred. If only segmented transfer is used, then
 * buffer size can be as low as 7 bytes, if data are read/written each cycle. If
 * block transfer is used, buffer size should be set to at least 889 bytes, so
 * maximum blksize can be used. In that case data should be read/written proper
 * time between cycles.
 */
#ifdef CO_DOXYGEN
#define CO_CONFIG_SDO_CLI_BUFFER_SIZE 32
```

```
#endif


/**
 * Configuration of TIME
 *
 * Possible flags, can be ORed:
 * - #CO_CONFIG_FLAG_CALLBACK_PRE - Enable custom callback after preprocessing
 *   received TIME CAN message.
 *   Callback is configured by CO_TIME_initCallbackPre().
 */
#ifdef CO_DOXYGEN
#define CO_CONFIG_TIME (CO_CONFIG_FLAG_CALLBACK_PRE)
#endif


/**
 * Configuration of LEDs object
 *
 * Possible flags, can be ORed:
 * - #CO_CONFIG_FLAG_TIMERNEXT - Enable calculation of timerNext_us variable
 *   inside CO_NMT_process().
 * - CO_CONFIG_LEDS_ENABLE - Enable calculation of the CANopen LED indicators.
 */
#ifdef CO_DOXYGEN
#define CO_CONFIG_LEDS (CO_CONFIG_FLAG_TIMERNEXT | CO_CONFIG_LEDS_ENABLE)
#endif
#define CO_CONFIG_LEDS_ENABLE 0x00


/**
 * Configuration of LSS objects
 *
 * Possible flags, can be ORed:
 * - #CO_CONFIG_FLAG_CALLBACK_PRE - Enable custom callback after preprocessing
 *   received CAN message.
 *   Callback is configured by CO_LSSmaster_initCallbackPre().
 * - CO_CONFIG_LSS_SLAVE - Enable LSS slave
 * - CO_CONFIG_LSS_SLAVE_FASTSCAN_DIRECT_RESPOND - Send LSS fastscan respond
 *   directly from CO_LSSslave_receive() function.
 * - CO_CONFIG_LSS_MASTER - Enable LSS master
 */
#ifdef CO_DOXYGEN
#define CO_CONFIG_LSS (CO_CONFIG_FLAG_CALLBACK_PRE | CO_CONFIG_LSS_SLAVE |
CO_CONFIG_LSS_SLAVE_FASTSCAN_DIRECT_RESPOND | CO_CONFIG_LSS_MASTER )
#endif
#define CO_CONFIG_LSS_SLAVE 0x00
#define CO_CONFIG_LSS_SLAVE_FASTSCAN_DIRECT_RESPOND 0x02
#define CO_CONFIG_LSS_MASTER 0x00


/**
 * Configuration of gateway object usage.
 *
 * Gateway object is covered by standard CiA 309 - CANopen access from other
 * networks. It enables usage of the NMT master, SDO client and LSS master as a
 * gateway device.
 *
 * Possible flags, can be ORed:
 * - CO_CONFIG_GTW_MULTI_NET - Enable multiple network interfaces in gateway
 *   device. This functionality is currently not implemented.
 * - CO_CONFIG_GTW_ASCII - Enable gateway device with ASCII mapping (CiA 309-3)
 * - CO_CONFIG_GTW_ASCII_SDO - Enable SDO client
 * - CO_CONFIG_GTW_ASCII_NMT - Enable NMT master
```

```
 * - CO_CONFIG_GTW_ASCII_LSS - Enable LSS master
 * - CO_CONFIG_GTW_ASCII_LOG - Enable non-standard message log read
 * - CO_CONFIG_GTW_ASCII_ERROR_DESC - Print error description as additional
 *   comments in gateway-ascii device for SDO and gateway errors.
 * - CO_CONFIG_GTW_ASCII_PRINT_HELP - use non-standard command "help" to print
 *   help usage.
 * - CO_CONFIG_GTW_ASCII_PRINT_LEDS - Display "red" and "green" CANopen status
 *   LED diodes on terminal.
 */
#ifdef CO_DOXYGEN
#define CO_CONFIG_GTW (CO_CONFIG_GTW_MULTI_NET | CO_CONFIG_GTW_ASCII |
CO_CONFIG_GTW_ASCII_SDO | CO_CONFIG_GTW_ASCII_NMT | CO_CONFIG_GTW_ASCII_LSS |
CO_CONFIG_GTW_ASCII_LOG | CO_CONFIG_GTW_ASCII_ERROR_DESC | CO_CONFIG_GTW_ASCII_PRINT_HELP
| CO_CONFIG_GTW_ASCII_PRINT_LEDS)
#endif
#define CO_CONFIG_GTW_MULTI_NET 0x01
#define CO_CONFIG_GTW_ASCII 0x02
#define CO_CONFIG_GTW_ASCII_SDO 0x04
#define CO_CONFIG_GTW_ASCII_NMT 0x08
#define CO_CONFIG_GTW_ASCII_LSS 0x10
#define CO_CONFIG_GTW_ASCII_LOG 0x20
#define CO_CONFIG_GTW_ASCII_ERROR_DESC 0x40
#define CO_CONFIG_GTW_ASCII_PRINT_HELP 0x80
#define CO_CONFIG_GTW_ASCII_PRINT_LEDS 0x100


/**
 * Number of loops of #CO_SDOclientDownload() in case of block download
 *
 * If SDO clint has block download in progress and OS has buffer for CAN tx
 * messages, then #CO_SDOclientDownload() functionion can be called multiple
 * times within own loop (up to 127). This can speed-up SDO block transfer.
 */
#ifdef CO_DOXYGEN
#define CO_CONFIG_GTW_BLOCK_DL_LOOP 1
#endif


/**
 * Size of command buffer in ASCII gateway object.
 *
 * If large amount of data is transferred (block transfer), then this should be
 * increased to 1000 or more. Buffer may be refilled between the block transfer.
 */
#ifdef CO_DOXYGEN
#define CO_CONFIG_GTWA_COMM_BUF_SIZE 200
#endif


/**
 * Size of message log buffer in ASCII gateway object.
 */
#ifdef CO_DOXYGEN
#define CO_CONFIG_GTWA_LOG_BUF_SIZE 2000
#endif


/** @} */

#ifdef __cplusplus
}
#endif /* __cplusplus */

#endif /* CO_CONFIG_FLAGS_H */
```

Fails “CO_driver_custom.h”

```
#include <stdint.h>
#include <stdbool.h>

#include "system_config.h"

#define TMR_TASK_INTERVAL 1000
#define CO_FSYS  SYS_CLK_BUS_PERIPHERAL_5 / 1000ul
#define CANAAPP_BITRATE 125//125//1000//125

/*
 * SDO server timeout in ms
 */
#define CO_SDO_SERVER_TIMEOUT 20

/*
 * ENable CO block transfer in CANopenApp SDO client upload/download
 */
#define CO_SDO_BLOCK_TRANSFER_ENABLE false
```

Fails "CO_driver_target.h"

```
/*
 * Microchip PIC32MX specific definitions for CANopenNode.
 *
 * @file        CO_driver_target.h
 * @author      Janez Paternoster
 * @copyright   2004 - 2020 Janez Paternoster
 *
 * This file is part of CANopenNode, an opensource CANopen Stack.
 * Project home page is <https://github.com/CANopenNode/CANopenNode>.
 * For more information on CANopen see <http://www.can-cia.org/>.
 *
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 * limitations under the License.
 */


#ifndef CO_DRIVER_TARGET
#define CO_DRIVER_TARGET

/* This file contains device and application specific definitions.
 * It is included from CO_driver.h, which contains documentation
 * for definitions below. */

#include <p32xxxx.h>
#include <stddef.h>
#include <stdbool.h>
#include <stdint.h>

#define CO_DRIVER_CUSTOM

#ifdef CO_DRIVER_CUSTOM
#include "CO_driver_custom.h"
#endif

#ifdef __cplusplus
extern "C" {
#endif

/* Stack configuration override from CO_driver.h.
 * For more information see file CO_config.h. */
#ifndef CO_CONFIG_NMT
#define CO_CONFIG_NMT CO_CONFIG_NMT_MASTER
#endif

#ifndef CO_CONFIG_SDO_BUFFER_SIZE
#define CO_CONFIG_SDO_BUFFER_SIZE 950
#endif

/* Basic definitions */
#define CO_LITTLE_ENDIAN
/* NULL is defined in stddef.h */
/* true and false are defined in stdbool.h */
/* int8_t to uint64_t are defined in stdint.h */
```

```
typedef unsigned char           bool_t;
typedef float                   float32_t;
typedef long double             float64_t;
typedef char                    char_t;
typedef unsigned char           oChar_t;
typedef unsigned char           domain_t;


/* CAN receive message structure as aligned in CAN module. */
typedef struct {
    unsigned    ident    :11;   /* Standard Identifier */
    unsigned    FILHIT   :5;    /* Filter hit, see PIC32MX documentation */
    unsigned    CMSGTS   :16;   /* CAN message timestamp, see PIC32MX documentation */
    unsigned    DLC      :4;    /* Data length code (bits 0...3) */
    unsigned             :5;
    unsigned    RTR      :1;    /* Remote Transmission Request bit */
    unsigned             :22;
    uint8_t     data[8];        /* 8 data bytes */
} CO_CANrxMsg_t;

/* Access to received CAN message */
#define CO_CANrxMsg_readIdent(msg)  ((uint16_t)(((CO_CANrxMsg_t *)(msg))->ident))
#define CO_CANrxMsg_readDLC(msg)    ((uint8_t)(((CO_CANrxMsg_t *)(msg))->DLC))
#define CO_CANrxMsg_readData(msg)   ((uint8_t *)(((CO_CANrxMsg_t *)(msg))->data))

/* Received message object */
typedef struct {
    uint16_t ident;
    uint16_t mask;
    void *object;
    void (*CANrx_callback)(void *object, void *message);
} CO_CANrx_t;

/* Transmit message object */
typedef struct {
    uint32_t  CMSGSID;     /* Equal to register in transmit message buffer. Includes
standard Identifier */
    uint32_t  CMSGEID;     /* Equal to register in transmit message buffer. Includes data
length code and RTR */
    uint8_t data[8];
    volatile bool_t bufferFull;
    volatile bool_t syncFlag;
} CO_CANtx_t;

/* CAN module object */
typedef struct {
    void *CANptr;
    CO_CANrxMsg_t CANmsgBuff[33]; /* PIC32 specific: CAN message buffer for CAN module. 32
buffers for receive, 1 buffer for transmit */
    uint8_t CANmsgBuffSize; /* PIC32 specific: Size of the above buffer == 33. Take care
initial value! */
    CO_CANrx_t *rxArray;
    uint16_t rxSize;
    CO_CANtx_t *txArray;
    uint16_t txSize;
    uint16_t CANerrorStatus;
    volatile bool_t CANnormal;
    volatile bool_t useCANrxFilters;
    volatile bool_t bufferInhibitFlag;
    volatile bool_t firstCANtxMessage;
    volatile uint16_t CANtxCount;
    uint32_t errOld;
} CO_CANmodule_t;
```

```
/* (un)lock critical section in CO_CANsend() */
extern unsigned int CO_interruptStatus;
#define CO_LOCK_CAN_SEND()      CO_interruptStatus = __builtin_disable_interrupts()
#define CO_UNLOCK_CAN_SEND()    if(CO_interruptStatus & 0x00000001)
{__builtin_enable_interrupts();}

/* (un)lock critical section in CO_errorReport() or CO_errorReset() */
#define CO_LOCK_EMCY()          CO_interruptStatus = __builtin_disable_interrupts()
#define CO_UNLOCK_EMCY()        if(CO_interruptStatus & 0x00000001)
{__builtin_enable_interrupts();}

/* (un)lock critical section when accessing Object Dictionary */
#define CO_LOCK_OD()            CO_interruptStatus = __builtin_disable_interrupts()
#define CO_UNLOCK_OD()          if(CO_interruptStatus & 0x00000001)
{__builtin_enable_interrupts();}

/* Synchronization between CAN receive and message processing threads. */
#define CO_MemoryBarrier()
#define CO_FLAG_READ(rxNew) ((rxNew) != NULL)
#define CO_FLAG_SET(rxNew) {CO_MemoryBarrier(); rxNew = (void*)1L;}
#define CO_FLAG_CLEAR(rxNew) {CO_MemoryBarrier(); rxNew = NULL;}


/* Translate a kernel virtual address in KSEG0 or KSEG1 to a real
 * physical address and back. */
typedef unsigned long CO_paddr_t; /* a physical address */
typedef unsigned long CO_vaddr_t; /* a virtual address */
#define CO_KVA_TO_PA(v)         ((CO_paddr_t)(v) & 0x1fffffff)
#define CO_PA_TO_KVA0(pa)       ((void *) ((pa) | 0x80000000))
#define CO_PA_TO_KVA1(pa)       ((void *) ((pa) | 0xa0000000))


/* CAN bit rates
 *
 * CAN bit rates are initializers for array of eight CO_CANbitRateData_t
 * objects.
 *
 * Macros are not used by driver itself, they may be used by application with
 * combination with object CO_CANbitRateData_t.
 * Application must declare following global variable depending on CO_FSYS used:
 * const CO_CANbitRateData_t  CO_CANbitRateData[8] = {CO_CANbitRateDataInitializers};
 *
 * There are initializers for eight objects, which corresponds to following
 * CAN bit rates (in kbps): 10, 20, 50, 125, 250, 500, 800, 1000.
 *
 * CO_FSYS is internal instruction cycle clock frequency in kHz units. See
 * PIC32MX documentation for more information on FSYS.
 *
 * Available values for FSYS:
 *    kbps = | 10 | 20 | 50 | 125 | 250 | 500 | 800 | 1000
 *    -------+----+----+----+-----+-----+-----+-----+-----
 *     4 Mhz |  O |  O |  O |  O  |  p  |  -  |  -  |  -
 *     8 Mhz |  O |  O |  O |  O  |  O  |  p  |  -  |  -
 *    12 Mhz |  O |  O |  O |  O  |  p  |  p  |  -  |  -
 *    16 Mhz |  O |  O |  O |  O  |  O  |  O  |  p  |  p
 *    20 Mhz |  O |  O |  O |  O  |  O  |  O  |  -  |  p
 *    24 Mhz |  O |  O |  O |  O  |  O  |  p  |  O  |  p
 *    32 Mhz |  p |  O |  O |  O  |  O  |  O  |  p  |  O
 *    36 Mhz |  - |  O |  O |  O  |  O  |  O  |  -  |  O
 *    40 Mhz |  - |  O |  O |  O  |  O  |  O  |  p  |  O
 *    48 Mhz |  - |  O |  O |  O  |  O  |  O  |  O  |  p
 *    56 Mhz |  - |  p |  O |  O  |  O  |  p  | (p) |  p
 *    64 Mhz |  - |  p |  O |  O  |  O  |  O  |  O  |  O
```

```
 *    72 Mhz |  - |  - | O | O  | O  | O  | O  | O
 *    80 Mhz |  - |  - | O | O  | O  | O  | p  | O
 *    -----------------------------------------------
 *    (O=optimal; p=possible; -=not possible)
 */
#ifdef CO_FSYS
    /* Macros, which divides K into (SJW + PROP + PhSeg1 + PhSeg2) */
    #define TQ_x_7    1, 2, 3, 1
    #define TQ_x_8    1, 2, 3, 2
    #define TQ_x_9    1, 2, 4, 2
    #define TQ_x_10   1, 3, 4, 2
    #define TQ_x_12   1, 3, 6, 2
    #define TQ_x_14   1, 4, 7, 2
    #define TQ_x_15   1, 4, 8, 2  /* good timing */
    #define TQ_x_16   1, 5, 8, 2  /* good timing */
    #define TQ_x_17   1, 6, 8, 2  /* good timing */
    #define TQ_x_18   1, 7, 8, 2  /* good timing */
    #define TQ_x_19   1, 8, 8, 2  /* good timing */
    #define TQ_x_20   1, 8, 8, 3  /* good timing */
    #define TQ_x_21   1, 8, 8, 4
    #define TQ_x_22   1, 8, 8, 5
    #define TQ_x_23   1, 8, 8, 6
    #define TQ_x_24   1, 8, 8, 7
    #define TQ_x_25   1, 8, 8, 8

    #if CO_FSYS == 4000
        #define CO_CANbitRateDataInitializers  \
        {10,  TQ_x_20, 10}, \
        {5,   TQ_x_20, 20}, \
        {2,   TQ_x_20, 50}, \
        {1,   TQ_x_16, 125}, \
        {1,   TQ_x_8 , 250}, \
        {1,   TQ_x_8 , 0}, \
        {1,   TQ_x_8 , 0}, \
        {1,   TQ_x_8 , 0}
    #elif CO_FSYS == 8000
        #define CO_CANbitRateDataInitializers  \
        {25,  TQ_x_16, 10}, \
        {10,  TQ_x_20, 20}, \
        {5,   TQ_x_16, 50}, \
        {2,   TQ_x_16, 125}, \
        {1,   TQ_x_16, 250}, \
        {1,   TQ_x_8 , 500}, \
        {1,   TQ_x_8 , 0}, \
        {1,   TQ_x_8 , 0}
    #elif CO_FSYS == 12000
        #define CO_CANbitRateDataInitializers  \
        {40,  TQ_x_15, 10}, \
        {20,  TQ_x_15, 20}, \
        {8,   TQ_x_15, 50}, \
        {3,   TQ_x_16, 125}, \
        {2,   TQ_x_12, 250}, \
        {1,   TQ_x_12, 500}, \
        {1,   TQ_x_12, 0}, \
        {1,   TQ_x_12, 0}
    #elif CO_FSYS == 16000
        #define CO_CANbitRateDataInitializers  \
        {50,  TQ_x_16, 10}, \
        {25,  TQ_x_16, 20}, \
        {10,  TQ_x_16, 50}, \
        {4,   TQ_x_16, 125}, \
        {2,   TQ_x_16, 250}, \
        {1,   TQ_x_16, 500}, \
        {1,   TQ_x_10, 800}, \
```

```
    {1,   TQ_x_8 , 1000}
#elif CO_FSYS == 20000
    #define CO_CANbitRateDataInitializers  \
    {50,  TQ_x_20, 10}, \
    {25,  TQ_x_20, 20}, \
    {10,  TQ_x_20, 50}, \
    {5,   TQ_x_16, 125}, \
    {2,   TQ_x_20, 250}, \
    {1,   TQ_x_20, 500}, \
    {1,   TQ_x_20, 0}, \
    {1,   TQ_x_10, 1000}
#elif CO_FSYS == 24000
    #define CO_CANbitRateDataInitializers  \
    {63,  TQ_x_19, 10}, \
    {40,  TQ_x_15, 20}, \
    {15,  TQ_x_16, 50}, \
    {6,   TQ_x_16, 125}, \
    {3,   TQ_x_16, 250}, \
    {2,   TQ_x_12, 500}, \
    {1,   TQ_x_15, 800}, \
    {1,   TQ_x_12, 1000}
#elif CO_FSYS == 32000
    #define CO_CANbitRateDataInitializers  \
    {64,  TQ_x_25, 10}, \
    {50,  TQ_x_16, 20}, \
    {20,  TQ_x_16, 50}, \
    {8,   TQ_x_16, 125}, \
    {4,   TQ_x_16, 250}, \
    {2,   TQ_x_16, 500}, \
    {2,   TQ_x_10, 800}, \
    {1,   TQ_x_16, 1000}
#elif CO_FSYS == 36000
    #define CO_CANbitRateDataInitializers  \
    {50,  TQ_x_18, 10}, \
    {50,  TQ_x_18, 20}, \
    {20,  TQ_x_18, 50}, \
    {8,   TQ_x_18, 125}, \
    {4,   TQ_x_18, 250}, \
    {2,   TQ_x_18, 500}, \
    {2,   TQ_x_18, 0}, \
    {1,   TQ_x_18, 1000}
#elif CO_FSYS == 40000
    #define CO_CANbitRateDataInitializers  \
    {50,  TQ_x_20, 0}, \
    {50,  TQ_x_20, 20}, \
    {25,  TQ_x_16, 50}, \
    {10,  TQ_x_16, 125}, \
    {5,   TQ_x_16, 250}, \
    {2,   TQ_x_20, 500}, \
    {1,   TQ_x_25, 800}, \
    {1,   TQ_x_20, 1000}
#elif CO_FSYS == 48000
    #define CO_CANbitRateDataInitializers  \
    {63,  TQ_x_19, 0}, \
    {63,  TQ_x_19, 20}, \
    {30,  TQ_x_16, 50}, \
    {12,  TQ_x_16, 125}, \
    {6,   TQ_x_16, 250}, \
    {3,   TQ_x_16, 500}, \
    {2,   TQ_x_15, 800}, \
    {2,   TQ_x_12, 1000}
#elif CO_FSYS == 56000
    #define CO_CANbitRateDataInitializers  \
    {61,  TQ_x_23, 0}, \
```

```
        {61,  TQ_x_23, 20}, \
        {35,  TQ_x_16, 50}, \
        {14,  TQ_x_16, 125}, \
        {7,   TQ_x_16, 250}, \
        {4,   TQ_x_14, 500}, \
        {5,   TQ_x_7 , 800}, \
        {2,   TQ_x_14, 1000}
    #elif CO_FSYS == 64000
        #define CO_CANbitRateDataInitializers  \
        {64,  TQ_x_25, 0}, \
        {64,  TQ_x_25, 20}, \
        {40,  TQ_x_16, 50}, \
        {16,  TQ_x_16, 125}, \
        {8,   TQ_x_16, 250}, \
        {4,   TQ_x_16, 500}, \
        {2,   TQ_x_20, 800}, \
        {2,   TQ_x_16, 1000}
    #elif CO_FSYS == 72000
        #define CO_CANbitRateDataInitializers  \
        {40,  TQ_x_18, 0}, \
        {40,  TQ_x_18, 0}, \
        {40,  TQ_x_18, 50}, \
        {16,  TQ_x_18, 125}, \
        {8,   TQ_x_18, 250}, \
        {4,   TQ_x_18, 500}, \
        {3,   TQ_x_15, 800}, \
        {2,   TQ_x_18, 1000}
    #elif CO_FSYS == 80000
        #define CO_CANbitRateDataInitializers  \
        {40,  TQ_x_20, 0}, \
        {40,  TQ_x_20, 0}, \
        {40,  TQ_x_20, 50}, \
        {16,  TQ_x_20, 125}, \
        {8,   TQ_x_20, 250}, \
        {4,   TQ_x_20, 500}, \
        {2,   TQ_x_25, 800}, \
        {2,   TQ_x_20, 1000}
    #elif CO_FSYS == 100000
        #define CO_CANbitRateDataInitializers  \       //Pievienots darbam ar 200 MHz
mikrokontrolleri
        {50,  TQ_x_20, 0},   /*Not possible*/     \
        {50,  TQ_x_20, 0},   /*Not possible*/     \
        {50,  TQ_x_20, 50},   /*CAN=50kbps*/       \
        {20,  TQ_x_20, 125},   /*CAN=125kbps*/      \
        {10,  TQ_x_20, 250},   /*CAN=250kbps*/      \
        {5,   TQ_x_20, 500},   /*CAN=500kbps*/      \
        {2,   TQ_x_25, 0},   /*Not possible*/      \
        {2,   TQ_x_25, 1000}    /*CAN=1000kbps*/
    #else
        #error define_CO_FSYS CO_FSYS not supported
    #endif
#endif

/* Structure contains timing coefficients for CAN module.
 *
 * CAN baud rate is calculated from following equations:
 * Fsys                                - System clock (MAX 80MHz for PIC32MX)
 * TQ = 2 * BRP / Fsys                 - Time Quanta
 * BaudRate = 1 / (TQ * K)             - Can bus Baud Rate
 * K = SJW + PROP + PhSeg1 + PhSeg2    - Number of Time Quantas
 */
typedef struct {
    uint8_t   BRP;      /* (1...64) Baud Rate Prescaler */
    uint8_t   SJW;      /* (1...4) SJW time */
```

```
    uint8_t   PROP;      /* (1...8) PROP time */
    uint8_t   phSeg1;    /* (1...8) Phase Segment 1 time */
    uint8_t   phSeg2;    /* (1...8) Phase Segment 2 time */
    uint16_t  bitrate;  /* bitrate in kbps */
} CO_CANbitRateData_t;

#ifdef __cplusplus
}
#endif /* __cplusplus */

#endif /* CO_DRIVER_TARGET */
```

Fails “CO_OD.c”

```
// clang-format off
/*******************************************************************************

   File - CO_OD.c/CO_OD.h
   CANopen Object Dictionary.

   This file was automatically generated with libedssharp Object
   Dictionary Editor vUnknown   DON'T EDIT THIS FILE MANUALLY !!!!
*******************************************************************************/


#include "CO_driver.h"
#include "CO_OD.h"
#include "CO_SDOserver.h"

/*******************************************************************************
   DEFINITION AND INITIALIZATION OF OBJECT DICTIONARY VARIABLES
*******************************************************************************/


/***** Definition for ROM variables ********************************************/
struct sCO_OD_ROM CO_OD_ROM = {
           CO_OD_FIRST_LAST_WORD,


           CO_OD_FIRST_LAST_WORD,
};


/***** Definition for RAM variables ********************************************/
struct sCO_OD_RAM CO_OD_RAM = {
           CO_OD_FIRST_LAST_WORD,

/*0005*/ 0x0L,
/*1000*/ 0x0000L,
/*1001*/ 0x0L,
/*1002*/ 0x0000L,
/*1003*/ {0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L},
/*1006*/ 0x3A98L,
/*1007*/ 0x07D0L,
/*1008*/ {'C', 'A', 'N', 'o', 'p', 'e', 'n', 'N', 'o', 'd', 'e'},
/*1009*/ {'3', '.', '0', '0'},
/*100A*/ {'3', '.', '0', '0'},
/*1010*/ {0x0003L},
/*1011*/ {0x0001L},
/*1014*/ 0x0080L,
/*1015*/ 0x64,
/*1016*/ {0x503FFL, 0x603FFL, 0x0000L, 0x0000L},
/*1017*/ 0x00,
/*1018*/ {0x4L, 0x0000L, 0x0000L, 0x0000L, 0x0000L},
/*1019*/ 0x0L,
/*1029*/ {0x0L, 0x0L, 0x1L, 0x0L, 0x0L, 0x0L},
/*1200*/ {{0x2L, 0x0600L, 0x0580L}},
/*1280*/ {{0x3L, 0x0600L, 0x0580L, 0x5L}},
/*1400*/ {{0x2L, 0x0281L, 0xFFL},
/*1401*/ {0x2L, 0x0282L, 0xFFL},
/*1402*/ {0x2L, 0x0283L, 0xFFL},
/*1403*/ {0x2L, 0x0284L, 0xFFL},
/*1404*/ {0x2L, 0x0285L, 0xFFL},
/*1405*/ {0x2L, 0x0286L, 0xFFL},
/*1406*/ {0x2L, 0x028AL, 0xFEL},
/*1407*/ {0x2L, 0x028BL, 0xFFL},
```

```
/*1408*/ {0x2L, 0x028CL, 0xFFL},
/*1409*/ {0x2L, 0x028DL, 0xFFL}},
/*1600*/ {{0x2L, 0x60110010L, 0x60120020L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L,
0x0000L},
/*1601*/ {0x2L, 0x60210010L, 0x60220020L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L,
0x0000L},
/*1602*/ {0x2L, 0x60310010L, 0x60320020L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L,
0x0000L},
/*1603*/ {0x2L, 0x60410010L, 0x60420020L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L,
0x0000L},
/*1604*/ {0x2L, 0x60510010L, 0x60520020L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L,
0x0000L},
/*1605*/ {0x2L, 0x60610010L, 0x60620020L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L,
0x0000L},
/*1606*/ {0x2L, 0x60A10010L, 0x60A30010L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L,
0x0000L},
/*1607*/ {0x2L, 0x60B10010L, 0x60B30010L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L,
0x0000L},
/*1608*/ {0x2L, 0x60C10010L, 0x60C30010L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L,
0x0000L},
/*1609*/ {0x2L, 0x60D10010L, 0x60D30010L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L,
0x0000L}},
/*1800*/ {{0x6L, 0x0301L, 0xFFL, 0x64, 0x0L, 0x00, 0x0L},
/*1801*/ {0x6L, 0x0302L, 0xFFL, 0x00, 0x0L, 0x00, 0x0L},
/*1802*/ {0x6L, 0x0303L, 0xFFL, 0x00, 0x0L, 0x00, 0x0L},
/*1803*/ {0x6L, 0x0304L, 0xFFL, 0x00, 0x0L, 0x00, 0x0L},
/*1804*/ {0x6L, 0x0305L, 0xFFL, 0x00, 0x0L, 0x00, 0x0L},
/*1805*/ {0x6L, 0x0306L, 0xFFL, 0x00, 0x0L, 0x00, 0x0L},
/*1806*/ {0x6L, 0x030AL, 0xFFL, 0x00, 0x0L, 0x00, 0x0L},
/*1807*/ {0x6L, 0x030BL, 0xFFL, 0x00, 0x0L, 0x00, 0x0L},
/*1808*/ {0x6L, 0x030CL, 0xFFL, 0x00, 0x0L, 0x00, 0x0L},
/*1809*/ {0x6L, 0x030DL, 0xFFL, 0x00, 0x0L, 0x00, 0x0L}},
/*1A00*/ {{0x2L, 0x60100010L, 0x60140020L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L,
0x0000L},
/*1A01*/ {0x2L, 0x60200010L, 0x60240020L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L,
0x0000L},
/*1A02*/ {0x2L, 0x60300010L, 0x60340020L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L,
0x0000L},
/*1A03*/ {0x2L, 0x60400010L, 0x60440020L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L,
0x0000L},
/*1A04*/ {0x2L, 0x60500010L, 0x60540020L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L,
0x0000L},
/*1A05*/ {0x2L, 0x60600010L, 0x60640020L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L,
0x0000L},
/*1A06*/ {0x2L, 0x60A00010L, 0x60A20010L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L,
0x0000L},
/*1A07*/ {0x2L, 0x60B00010L, 0x60B20010L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L,
0x0000L},
/*1A08*/ {0x2L, 0x60C00010L, 0x60C20010L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L,
0x0000L},
/*1A09*/ {0x2L, 0x60D00010L, 0x60D20010L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L,
0x0000L}},
/*1F80*/ 0x0001L,
/*2100*/ {0x0L},
/*2101*/ 0x30L,
/*2102*/ 0xFA,
/*2103*/ 0x00,
/*2104*/ 0x00,
/*2106*/ 0x0000L,
/*2107*/ {0x3E8, 0x00, 0x00, 0x00, 0x00},
/*2108*/ {0x00},
/*2109*/ {0x00},
/*2110*/ {0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L,
0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L},
```

```
/*2111*/ {0x0001L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L,
0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L},
/*2112*/ {0x0001L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L,
0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0x0000L},
/*2120*/ {0x5L, 0x1234567890ABCDEFL, 0x234567890ABCDEF1L, 12.345, 456.789, 0},
/*2130*/ {0x3L, {'-'}, 0x00000000L, 0x0000L},
/*2301*/ {{0x8L, 0x0064L, 0x1L, {'T', 'r', 'a', 'c', 'e', '1'}, {'r', 'e', 'd'},
0x60000108L, 0x1L, 0x0L, 0x0000L},
/*2302*/ {0x8L, 0x0000L, 0x0L, {'T', 'r', 'a', 'c', 'e', '2'}, {'g', 'r', 'e', 'e', 'n'},
0x0000L, 0x0L, 0x0L, 0x0000L}},
/*2400*/ 0x0L,
/*2401*/ {{0x6L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0, 0x0000L},
/*2402*/ {0x6L, 0x0000L, 0x0000L, 0x0000L, 0x0000L, 0, 0x0000L}},
/*6010*/ 0x00,
/*6011*/ 0x00,
/*6012*/ 0x0000L,
/*6013*/ 0x0000L,
/*6014*/ 0x0000L,
/*6015*/ 0x0000L,
/*6020*/ 0x00,
/*6021*/ 0x00,
/*6022*/ 0x0000L,
/*6023*/ 0x0000L,
/*6024*/ 0x0000L,
/*6025*/ 0x0000L,
/*6030*/ 0x00,
/*6031*/ 0x00,
/*6032*/ 0x0000L,
/*6033*/ 0x0000L,
/*6034*/ 0x0000L,
/*6035*/ 0x0000L,
/*6040*/ 0x00,
/*6041*/ 0x00,
/*6042*/ 0x0000L,
/*6043*/ 0x0000L,
/*6044*/ 0x0000L,
/*6045*/ 0x0000L,
/*6050*/ 0x00,
/*6051*/ 0x00,
/*6052*/ 0x0000L,
/*6053*/ 0x0000L,
/*6054*/ 0x0000L,
/*6055*/ 0x0000L,
/*6060*/ 0x00,
/*6061*/ 0x00,
/*6062*/ 0x0000L,
/*6063*/ 0x0000L,
/*6064*/ 0x0000L,
/*6065*/ 0x0000L,
/*60A0*/ 0x00,
/*60A1*/ 0x00,
/*60A2*/ 0x00,
/*60A3*/ 0x00,
/*60B0*/ 0x00,
/*60B1*/ 0x00,
/*60B2*/ 0x00,
/*60B3*/ 0x00,
/*60C0*/ 0x00,
/*60C1*/ 0x00,
/*60C2*/ 0x00,
/*60C3*/ 0x00,
/*60D0*/ 0x00,
/*60D1*/ 0x00,
/*60D2*/ 0x00,
```

```
/*60D3*/ 0x00,

           CO_OD_FIRST_LAST_WORD,
};


/***** Definition for EEPROM variables ******************************************/
struct sCO_OD_EEPROM CO_OD_EEPROM = {
           CO_OD_FIRST_LAST_WORD,


           CO_OD_FIRST_LAST_WORD,
};




/*******************************************************************************
   STRUCTURES FOR RECORD TYPE OBJECTS
*******************************************************************************/


/*0x1018*/ const CO_OD_entryRecord_t OD_record1018[5] = {
           {(void*)&CO_OD_RAM.identity.maxSubIndex, 0x06, 0x1 },
           {(void*)&CO_OD_RAM.identity.vendorID, 0x86, 0x4 },
           {(void*)&CO_OD_RAM.identity.productCode, 0x86, 0x4 },
           {(void*)&CO_OD_RAM.identity.revisionNumber, 0x86, 0x4 },
           {(void*)&CO_OD_RAM.identity.serialNumber, 0x86, 0x4 },
};

/*0x1200*/ const CO_OD_entryRecord_t OD_record1200[3] = {
           {(void*)&CO_OD_RAM.SDOServerParameter[0].maxSubIndex, 0x06, 0x1 },
           {(void*)&CO_OD_RAM.SDOServerParameter[0].COB_IDClientToServer, 0x86, 0x4 },
           {(void*)&CO_OD_RAM.SDOServerParameter[0].COB_IDServerToClient, 0x86, 0x4 },
};

/*0x1280*/ const CO_OD_entryRecord_t OD_record1280[4] = {
           {(void*)&CO_OD_RAM.SDOClientParameter[0].maxSubIndex, 0x06, 0x1 },
           {(void*)&CO_OD_RAM.SDOClientParameter[0].COB_IDClientToServer, 0x86, 0x4 },
           {(void*)&CO_OD_RAM.SDOClientParameter[0].COB_IDServerToClient, 0x86, 0x4 },
           {(void*)&CO_OD_RAM.SDOClientParameter[0].nodeIDOfTheSDOServer, 0x06, 0x1 },
};

/*0x1400*/ const CO_OD_entryRecord_t OD_record1400[3] = {
           {(void*)&CO_OD_RAM.RPDOCommunicationParameter[0].maxSubIndex, 0x06, 0x1 },
           {(void*)&CO_OD_RAM.RPDOCommunicationParameter[0].COB_IDUsedByRPDO, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.RPDOCommunicationParameter[0].transmissionType, 0x0E, 0x1 },
};

/*0x1401*/ const CO_OD_entryRecord_t OD_record1401[3] = {
           {(void*)&CO_OD_RAM.RPDOCommunicationParameter[1].maxSubIndex, 0x06, 0x1 },
           {(void*)&CO_OD_RAM.RPDOCommunicationParameter[1].COB_IDUsedByRPDO, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.RPDOCommunicationParameter[1].transmissionType, 0x0E, 0x1 },
};

/*0x1402*/ const CO_OD_entryRecord_t OD_record1402[3] = {
           {(void*)&CO_OD_RAM.RPDOCommunicationParameter[2].maxSubIndex, 0x06, 0x1 },
           {(void*)&CO_OD_RAM.RPDOCommunicationParameter[2].COB_IDUsedByRPDO, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.RPDOCommunicationParameter[2].transmissionType, 0x0E, 0x1 },
};

/*0x1403*/ const CO_OD_entryRecord_t OD_record1403[3] = {
           {(void*)&CO_OD_RAM.RPDOCommunicationParameter[3].maxSubIndex, 0x06, 0x1 },
           {(void*)&CO_OD_RAM.RPDOCommunicationParameter[3].COB_IDUsedByRPDO, 0x8E, 0x4 },
```

```
            {(void*)&CO_OD_RAM.RPDOCommunicationParameter[3].transmissionType, 0x0E, 0x1 },
};

/*0x1404*/ const CO_OD_entryRecord_t OD_record1404[3] = {
            {(void*)&CO_OD_RAM.RPDOCommunicationParameter[4].maxSubIndex, 0x06, 0x1 },
            {(void*)&CO_OD_RAM.RPDOCommunicationParameter[4].COB_IDUsedByRPDO, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.RPDOCommunicationParameter[4].transmissionType, 0x0E, 0x1 },
};

/*0x1405*/ const CO_OD_entryRecord_t OD_record1405[3] = {
            {(void*)&CO_OD_RAM.RPDOCommunicationParameter[5].maxSubIndex, 0x06, 0x1 },
            {(void*)&CO_OD_RAM.RPDOCommunicationParameter[5].COB_IDUsedByRPDO, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.RPDOCommunicationParameter[5].transmissionType, 0x0E, 0x1 },
};

/*0x1406*/ const CO_OD_entryRecord_t OD_record1406[3] = {
            {(void*)&CO_OD_RAM.RPDOCommunicationParameter[6].maxSubIndex, 0x06, 0x1 },
            {(void*)&CO_OD_RAM.RPDOCommunicationParameter[6].COB_IDUsedByRPDO, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.RPDOCommunicationParameter[6].transmissionType, 0x0E, 0x1 },
};

/*0x1407*/ const CO_OD_entryRecord_t OD_record1407[3] = {
            {(void*)&CO_OD_RAM.RPDOCommunicationParameter[7].maxSubIndex, 0x06, 0x1 },
            {(void*)&CO_OD_RAM.RPDOCommunicationParameter[7].COB_IDUsedByRPDO, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.RPDOCommunicationParameter[7].transmissionType, 0x0E, 0x1 },
};

/*0x1408*/ const CO_OD_entryRecord_t OD_record1408[3] = {
            {(void*)&CO_OD_RAM.RPDOCommunicationParameter[8].maxSubIndex, 0x06, 0x1 },
            {(void*)&CO_OD_RAM.RPDOCommunicationParameter[8].COB_IDUsedByRPDO, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.RPDOCommunicationParameter[8].transmissionType, 0x0E, 0x1 },
};

/*0x1409*/ const CO_OD_entryRecord_t OD_record1409[3] = {
            {(void*)&CO_OD_RAM.RPDOCommunicationParameter[9].maxSubIndex, 0x06, 0x1 },
            {(void*)&CO_OD_RAM.RPDOCommunicationParameter[9].COB_IDUsedByRPDO, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.RPDOCommunicationParameter[9].transmissionType, 0x0E, 0x1 },
};

/*0x1600*/ const CO_OD_entryRecord_t OD_record1600[9] = {
            {(void*)&CO_OD_RAM.RPDOMappingParameter[0].numberOfMappedObjects, 0x0E, 0x1 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[0].mappedObject1, 0xBE, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[0].mappedObject2, 0xBE, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[0].mappedObject3, 0xBE, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[0].mappedObject4, 0xBE, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[0].mappedObject5, 0xBE, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[0].mappedObject6, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[0].mappedObject7, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[0].mappedObject8, 0x8E, 0x4 },
};

/*0x1601*/ const CO_OD_entryRecord_t OD_record1601[9] = {
            {(void*)&CO_OD_RAM.RPDOMappingParameter[1].numberOfMappedObjects, 0x0E, 0x1 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[1].mappedObject1, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[1].mappedObject2, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[1].mappedObject3, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[1].mappedObject4, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[1].mappedObject5, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[1].mappedObject6, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[1].mappedObject7, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[1].mappedObject8, 0x8E, 0x4 },
};

/*0x1602*/ const CO_OD_entryRecord_t OD_record1602[9] = {
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            {(void*)&CO_OD_RAM.RPDOMappingParameter[2].numberOfMappedObjects, 0x0E, 0x1 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[2].mappedObject1, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[2].mappedObject2, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[2].mappedObject3, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[2].mappedObject4, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[2].mappedObject5, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[2].mappedObject6, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[2].mappedObject7, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[2].mappedObject8, 0x8E, 0x4 },
};

/*0x1603*/ const CO_OD_entryRecord_t OD_record1603[9] = {
            {(void*)&CO_OD_RAM.RPDOMappingParameter[3].numberOfMappedObjects, 0x0E, 0x1 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[3].mappedObject1, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[3].mappedObject2, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[3].mappedObject3, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[3].mappedObject4, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[3].mappedObject5, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[3].mappedObject6, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[3].mappedObject7, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[3].mappedObject8, 0x8E, 0x4 },
};

/*0x1604*/ const CO_OD_entryRecord_t OD_record1604[9] = {
            {(void*)&CO_OD_RAM.RPDOMappingParameter[4].numberOfMappedObjects, 0x06, 0x1 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[4].mappedObject1, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[4].mappedObject2, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[4].mappedObject3, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[4].mappedObject4, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[4].mappedObject5, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[4].mappedObject6, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[4].mappedObject7, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[4].mappedObject8, 0x86, 0x4 },
};

/*0x1605*/ const CO_OD_entryRecord_t OD_record1605[9] = {
            {(void*)&CO_OD_RAM.RPDOMappingParameter[5].numberOfMappedObjects, 0x06, 0x1 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[5].mappedObject1, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[5].mappedObject2, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[5].mappedObject3, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[5].mappedObject4, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[5].mappedObject5, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[5].mappedObject6, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[5].mappedObject7, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[5].mappedObject8, 0x86, 0x4 },
};

/*0x1606*/ const CO_OD_entryRecord_t OD_record1606[9] = {
            {(void*)&CO_OD_RAM.RPDOMappingParameter[6].numberOfMappedObjects, 0x06, 0x1 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[6].mappedObject1, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[6].mappedObject2, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[6].mappedObject3, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[6].mappedObject4, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[6].mappedObject5, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[6].mappedObject6, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[6].mappedObject7, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[6].mappedObject8, 0x86, 0x4 },
};

/*0x1607*/ const CO_OD_entryRecord_t OD_record1607[9] = {
            {(void*)&CO_OD_RAM.RPDOMappingParameter[7].numberOfMappedObjects, 0x06, 0x1 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[7].mappedObject1, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[7].mappedObject2, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[7].mappedObject3, 0x86, 0x4 },
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            {(void*)&CO_OD_RAM.RPDOMappingParameter[7].mappedObject4, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[7].mappedObject5, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[7].mappedObject6, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[7].mappedObject7, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[7].mappedObject8, 0x86, 0x4 },
};

/*0x1608*/ const CO_OD_entryRecord_t OD_record1608[9] = {
            {(void*)&CO_OD_RAM.RPDOMappingParameter[8].numberOfMappedObjects, 0x06, 0x1 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[8].mappedObject1, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[8].mappedObject2, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[8].mappedObject3, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[8].mappedObject4, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[8].mappedObject5, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[8].mappedObject6, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[8].mappedObject7, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[8].mappedObject8, 0x86, 0x4 },
};

/*0x1609*/ const CO_OD_entryRecord_t OD_record1609[9] = {
            {(void*)&CO_OD_RAM.RPDOMappingParameter[9].numberOfMappedObjects, 0x06, 0x1 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[9].mappedObject1, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[9].mappedObject2, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[9].mappedObject3, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[9].mappedObject4, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[9].mappedObject5, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[9].mappedObject6, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[9].mappedObject7, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.RPDOMappingParameter[9].mappedObject8, 0x86, 0x4 },
};

/*0x1800*/ const CO_OD_entryRecord_t OD_record1800[7] = {
            {(void*)&CO_OD_RAM.TPDOCommunicationParameter[0].maxSubIndex, 0x06, 0x1 },
            {(void*)&CO_OD_RAM.TPDOCommunicationParameter[0].COB_IDUsedByTPDO, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.TPDOCommunicationParameter[0].transmissionType, 0x0E, 0x1 },
            {(void*)&CO_OD_RAM.TPDOCommunicationParameter[0].inhibitTime, 0x8E, 0x2 },
            {(void*)&CO_OD_RAM.TPDOCommunicationParameter[0].compatibilityEntry, 0x0E, 0x1
},
            {(void*)&CO_OD_RAM.TPDOCommunicationParameter[0].eventTimer, 0x8E, 0x2 },
            {(void*)&CO_OD_RAM.TPDOCommunicationParameter[0].SYNCStartValue, 0x0E, 0x1 },
};

/*0x1801*/ const CO_OD_entryRecord_t OD_record1801[7] = {
            {(void*)&CO_OD_RAM.TPDOCommunicationParameter[1].maxSubIndex, 0x06, 0x1 },
            {(void*)&CO_OD_RAM.TPDOCommunicationParameter[1].COB_IDUsedByTPDO, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.TPDOCommunicationParameter[1].transmissionType, 0x0E, 0x1 },
            {(void*)&CO_OD_RAM.TPDOCommunicationParameter[1].inhibitTime, 0x8E, 0x2 },
            {(void*)&CO_OD_RAM.TPDOCommunicationParameter[1].compatibilityEntry, 0x0E, 0x1
},
            {(void*)&CO_OD_RAM.TPDOCommunicationParameter[1].eventTimer, 0x8E, 0x2 },
            {(void*)&CO_OD_RAM.TPDOCommunicationParameter[1].SYNCStartValue, 0x0E, 0x1 },
};

/*0x1802*/ const CO_OD_entryRecord_t OD_record1802[7] = {
            {(void*)&CO_OD_RAM.TPDOCommunicationParameter[2].maxSubIndex, 0x06, 0x1 },
            {(void*)&CO_OD_RAM.TPDOCommunicationParameter[2].COB_IDUsedByTPDO, 0x8E, 0x4 },
            {(void*)&CO_OD_RAM.TPDOCommunicationParameter[2].transmissionType, 0x0E, 0x1 },
            {(void*)&CO_OD_RAM.TPDOCommunicationParameter[2].inhibitTime, 0x8E, 0x2 },
            {(void*)&CO_OD_RAM.TPDOCommunicationParameter[2].compatibilityEntry, 0x0E, 0x1
},
            {(void*)&CO_OD_RAM.TPDOCommunicationParameter[2].eventTimer, 0x8E, 0x2 },
            {(void*)&CO_OD_RAM.TPDOCommunicationParameter[2].SYNCStartValue, 0x0E, 0x1 },
};
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/*0x1803*/ const CO_OD_entryRecord_t OD_record1803[7] = {
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[3].maxSubIndex, 0x06, 0x1 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[3].COB_IDUsedByTPDO, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[3].transmissionType, 0x0E, 0x1 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[3].inhibitTime, 0x8E, 0x2 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[3].compatibilityEntry, 0x0E, 0x1
},
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[3].eventTimer, 0x8E, 0x2 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[3].SYNCStartValue, 0x0E, 0x1 },
};

/*0x1804*/ const CO_OD_entryRecord_t OD_record1804[7] = {
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[4].maxSubIndex, 0x06, 0x1 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[4].COB_IDUsedByTPDO, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[4].transmissionType, 0x0E, 0x1 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[4].inhibitTime, 0x8E, 0x2 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[4].compatibilityEntry, 0x06, 0x1
},
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[4].eventTimer, 0x8E, 0x2 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[4].SYNCStartValue, 0x0E, 0x1 },
};

/*0x1805*/ const CO_OD_entryRecord_t OD_record1805[7] = {
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[5].maxSubIndex, 0x06, 0x1 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[5].COB_IDUsedByTPDO, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[5].transmissionType, 0x0E, 0x1 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[5].inhibitTime, 0x8E, 0x2 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[5].compatibilityEntry, 0x06, 0x1
},
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[5].eventTimer, 0x8E, 0x2 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[5].SYNCStartValue, 0x0E, 0x1 },
};

/*0x1806*/ const CO_OD_entryRecord_t OD_record1806[7] = {
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[6].maxSubIndex, 0x06, 0x1 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[6].COB_IDUsedByTPDO, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[6].transmissionType, 0x0E, 0x1 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[6].inhibitTime, 0x8E, 0x2 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[6].compatibilityEntry, 0x06, 0x1
},
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[6].eventTimer, 0x8E, 0x2 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[6].SYNCStartValue, 0x0E, 0x1 },
};

/*0x1807*/ const CO_OD_entryRecord_t OD_record1807[7] = {
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[7].maxSubIndex, 0x06, 0x1 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[7].COB_IDUsedByTPDO, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[7].transmissionType, 0x0E, 0x1 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[7].inhibitTime, 0x8E, 0x2 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[7].compatibilityEntry, 0x06, 0x1
},
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[7].eventTimer, 0x8E, 0x2 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[7].SYNCStartValue, 0x0E, 0x1 },
};

/*0x1808*/ const CO_OD_entryRecord_t OD_record1808[7] = {
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[8].maxSubIndex, 0x06, 0x1 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[8].COB_IDUsedByTPDO, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[8].transmissionType, 0x0E, 0x1 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[8].inhibitTime, 0x8E, 0x2 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[8].compatibilityEntry, 0x06, 0x1
},
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[8].eventTimer, 0x8E, 0x2 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[8].SYNCStartValue, 0x0E, 0x1 },
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};

/*0x1809*/ const CO_OD_entryRecord_t OD_record1809[7] = {
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[9].maxSubIndex, 0x06, 0x1 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[9].COB_IDUsedByTPDO, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[9].transmissionType, 0x0E, 0x1 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[9].inhibitTime, 0x8E, 0x2 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[9].compatibilityEntry, 0x06, 0x1
},
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[9].eventTimer, 0x8E, 0x2 },
           {(void*)&CO_OD_RAM.TPDOCommunicationParameter[9].SYNCStartValue, 0x0E, 0x1 },
};

/*0x1A00*/ const CO_OD_entryRecord_t OD_record1A00[9] = {
           {(void*)&CO_OD_RAM.TPDOMappingParameter[0].numberOfMappedObjects, 0x0E, 0x1 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[0].mappedObject1, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[0].mappedObject2, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[0].mappedObject3, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[0].mappedObject4, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[0].mappedObject5, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[0].mappedObject6, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[0].mappedObject7, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[0].mappedObject8, 0x8E, 0x4 },
};

/*0x1A01*/ const CO_OD_entryRecord_t OD_record1A01[9] = {
           {(void*)&CO_OD_RAM.TPDOMappingParameter[1].numberOfMappedObjects, 0x0E, 0x1 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[1].mappedObject1, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[1].mappedObject2, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[1].mappedObject3, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[1].mappedObject4, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[1].mappedObject5, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[1].mappedObject6, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[1].mappedObject7, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[1].mappedObject8, 0x8E, 0x4 },
};

/*0x1A02*/ const CO_OD_entryRecord_t OD_record1A02[9] = {
           {(void*)&CO_OD_RAM.TPDOMappingParameter[2].numberOfMappedObjects, 0x0E, 0x1 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[2].mappedObject1, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[2].mappedObject2, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[2].mappedObject3, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[2].mappedObject4, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[2].mappedObject5, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[2].mappedObject6, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[2].mappedObject7, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[2].mappedObject8, 0x8E, 0x4 },
};

/*0x1A03*/ const CO_OD_entryRecord_t OD_record1A03[9] = {
           {(void*)&CO_OD_RAM.TPDOMappingParameter[3].numberOfMappedObjects, 0x0E, 0x1 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[3].mappedObject1, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[3].mappedObject2, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[3].mappedObject3, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[3].mappedObject4, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[3].mappedObject5, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[3].mappedObject6, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[3].mappedObject7, 0x8E, 0x4 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[3].mappedObject8, 0x8E, 0x4 },
};

/*0x1A04*/ const CO_OD_entryRecord_t OD_record1A04[9] = {
           {(void*)&CO_OD_RAM.TPDOMappingParameter[4].numberOfMappedObjects, 0x06, 0x1 },
           {(void*)&CO_OD_RAM.TPDOMappingParameter[4].mappedObject1, 0x86, 0x4 },
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            {(void*)&CO_OD_RAM.TPDOMappingParameter[4].mappedObject2, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[4].mappedObject3, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[4].mappedObject4, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[4].mappedObject5, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[4].mappedObject6, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[4].mappedObject7, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[4].mappedObject8, 0x86, 0x4 },
};

/*0x1A05*/ const CO_OD_entryRecord_t OD_record1A05[9] = {
            {(void*)&CO_OD_RAM.TPDOMappingParameter[5].numberOfMappedObjects, 0x06, 0x1 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[5].mappedObject1, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[5].mappedObject2, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[5].mappedObject3, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[5].mappedObject4, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[5].mappedObject5, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[5].mappedObject6, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[5].mappedObject7, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[5].mappedObject8, 0x86, 0x4 },
};

/*0x1A06*/ const CO_OD_entryRecord_t OD_record1A06[9] = {
            {(void*)&CO_OD_RAM.TPDOMappingParameter[6].numberOfMappedObjects, 0x06, 0x1 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[6].mappedObject1, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[6].mappedObject2, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[6].mappedObject3, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[6].mappedObject4, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[6].mappedObject5, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[6].mappedObject6, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[6].mappedObject7, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[6].mappedObject8, 0x86, 0x4 },
};

/*0x1A07*/ const CO_OD_entryRecord_t OD_record1A07[9] = {
            {(void*)&CO_OD_RAM.TPDOMappingParameter[7].numberOfMappedObjects, 0x06, 0x1 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[7].mappedObject1, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[7].mappedObject2, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[7].mappedObject3, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[7].mappedObject4, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[7].mappedObject5, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[7].mappedObject6, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[7].mappedObject7, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[7].mappedObject8, 0x86, 0x4 },
};

/*0x1A08*/ const CO_OD_entryRecord_t OD_record1A08[9] = {
            {(void*)&CO_OD_RAM.TPDOMappingParameter[8].numberOfMappedObjects, 0x06, 0x1 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[8].mappedObject1, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[8].mappedObject2, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[8].mappedObject3, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[8].mappedObject4, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[8].mappedObject5, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[8].mappedObject6, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[8].mappedObject7, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[8].mappedObject8, 0x86, 0x4 },
};

/*0x1A09*/ const CO_OD_entryRecord_t OD_record1A09[9] = {
            {(void*)&CO_OD_RAM.TPDOMappingParameter[9].numberOfMappedObjects, 0x06, 0x1 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[9].mappedObject1, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[9].mappedObject2, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[9].mappedObject3, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[9].mappedObject4, 0x86, 0x4 },
            {(void*)&CO_OD_RAM.TPDOMappingParameter[9].mappedObject5, 0x86, 0x4 },
```

```
        {(void*)&CO_OD_RAM.TPDOMappingParameter[9].mappedObject6, 0x86, 0x4 },
        {(void*)&CO_OD_RAM.TPDOMappingParameter[9].mappedObject7, 0x86, 0x4 },
        {(void*)&CO_OD_RAM.TPDOMappingParameter[9].mappedObject8, 0x86, 0x4 },
};

/*0x2120*/ const CO_OD_entryRecord_t OD_record2120[6] = {
        {(void*)&CO_OD_RAM.testVar.maxSubIndex, 0x06, 0x1 },
        {(void*)&CO_OD_RAM.testVar.I64, 0x9E, 0x8 },
        {(void*)&CO_OD_RAM.testVar.U64, 0x9E, 0x8 },
        {(void*)&CO_OD_RAM.testVar.R32, 0x9E, 0x4 },
        {(void*)&CO_OD_RAM.testVar.R64, 0x9E, 0x8 },
        {(void*)0, 0x0E, 0x0 },
};

/*0x2130*/ const CO_OD_entryRecord_t OD_record2130[4] = {
        {(void*)&CO_OD_RAM.time.maxSubIndex, 0x06, 0x1 },
        {(void*)&CO_OD_RAM.time.string, 0x06, 0x1 },
        {(void*)&CO_OD_RAM.time.epochTimeBaseMs, 0x8E, 0x8 },
        {(void*)&CO_OD_RAM.time.epochTimeOffsetMs, 0x9E, 0x4 },
};

/*0x2301*/ const CO_OD_entryRecord_t OD_record2301[9] = {
        {(void*)&CO_OD_RAM.traceConfig[0].maxSubIndex, 0x06, 0x1 },
        {(void*)&CO_OD_RAM.traceConfig[0].size, 0x8E, 0x4 },
        {(void*)&CO_OD_RAM.traceConfig[0].axisNo, 0x0E, 0x1 },
        {(void*)&CO_OD_RAM.traceConfig[0].name, 0x0E, 0x6 },
        {(void*)&CO_OD_RAM.traceConfig[0].color, 0x0E, 0x3 },
        {(void*)&CO_OD_RAM.traceConfig[0].map, 0x8E, 0x4 },
        {(void*)&CO_OD_RAM.traceConfig[0].format, 0x0E, 0x1 },
        {(void*)&CO_OD_RAM.traceConfig[0].trigger, 0x0E, 0x1 },
        {(void*)&CO_OD_RAM.traceConfig[0].threshold, 0x8E, 0x4 },
};

/*0x2302*/ const CO_OD_entryRecord_t OD_record2302[9] = {
        {(void*)&CO_OD_RAM.traceConfig[1].maxSubIndex, 0x06, 0x1 },
        {(void*)&CO_OD_RAM.traceConfig[1].size, 0x8E, 0x4 },
        {(void*)&CO_OD_RAM.traceConfig[1].axisNo, 0x0E, 0x1 },
        {(void*)&CO_OD_RAM.traceConfig[1].name, 0x0E, 0x6 },
        {(void*)&CO_OD_RAM.traceConfig[1].color, 0x0E, 0x5 },
        {(void*)&CO_OD_RAM.traceConfig[1].map, 0x8E, 0x4 },
        {(void*)&CO_OD_RAM.traceConfig[1].format, 0x0E, 0x1 },
        {(void*)&CO_OD_RAM.traceConfig[1].trigger, 0x0E, 0x1 },
        {(void*)&CO_OD_RAM.traceConfig[1].threshold, 0x8E, 0x4 },
};

/*0x2401*/ const CO_OD_entryRecord_t OD_record2401[7] = {
        {(void*)&CO_OD_RAM.trace[0].maxSubIndex, 0x06, 0x1 },
        {(void*)&CO_OD_RAM.trace[0].size, 0x9E, 0x4 },
        {(void*)&CO_OD_RAM.trace[0].value, 0x9E, 0x4 },
        {(void*)&CO_OD_RAM.trace[0].min, 0x9E, 0x4 },
        {(void*)&CO_OD_RAM.trace[0].max, 0x9E, 0x4 },
        {(void*)0, 0x06, 0x0 },
        {(void*)&CO_OD_RAM.trace[0].triggerTime, 0x9E, 0x4 },
};

/*0x2402*/ const CO_OD_entryRecord_t OD_record2402[7] = {
        {(void*)&CO_OD_RAM.trace[1].maxSubIndex, 0x06, 0x1 },
        {(void*)&CO_OD_RAM.trace[1].size, 0x9E, 0x4 },
        {(void*)&CO_OD_RAM.trace[1].value, 0x9E, 0x4 },
        {(void*)&CO_OD_RAM.trace[1].min, 0x9E, 0x4 },
        {(void*)&CO_OD_RAM.trace[1].max, 0x9E, 0x4 },
        {(void*)0, 0x06, 0x0 },
        {(void*)&CO_OD_RAM.trace[1].triggerTime, 0x9E, 0x4 },
};
```

```
/*******************************************************************************
   OBJECT DICTIONARY
*******************************************************************************/
const CO_OD_entry_t CO_OD[CO_OD_NoOfElements] = {
{0x0005, 0x00, 0x06,  1, (void*)&CO_OD_RAM.compatabilityEntry},
{0x1000, 0x00, 0x86,  4, (void*)&CO_OD_RAM.deviceType},
{0x1001, 0x00, 0x26,  1, (void*)&CO_OD_RAM.errorRegister},
{0x1002, 0x00, 0xA6,  4, (void*)&CO_OD_RAM.manufacturerStatusRegister},
{0x1003, 0x08, 0x06,  0, (void*)&CO_OD_RAM.preDefinedErrorField[0]},
{0x1006, 0x00, 0x8E,  4, (void*)&CO_OD_RAM.communicationCyclePeriod},
{0x1007, 0x00, 0x8E,  4, (void*)&CO_OD_RAM.synchronousWindowLength},
{0x1008, 0x00, 0x06, 11, (void*)&CO_OD_RAM.manufacturerDeviceName},
{0x1009, 0x00, 0x06,  4, (void*)&CO_OD_RAM.manufacturerHardwareVersion},
{0x100A, 0x00, 0x06,  4, (void*)&CO_OD_RAM.manufacturerSoftwareVersion},
{0x1010, 0x01, 0x06,  0, (void*)&CO_OD_RAM.storeParameters[0]},
{0x1011, 0x01, 0x06,  0, (void*)&CO_OD_RAM.restoreDefaultParameters[0]},
{0x1014, 0x00, 0x86,  4, (void*)&CO_OD_RAM.COB_ID_EMCY},
{0x1015, 0x00, 0x8E,  2, (void*)&CO_OD_RAM.inhibitTimeEMCY},
{0x1016, 0x04, 0x06,  0, (void*)&CO_OD_RAM.consumerHeartbeatTime[0]},
{0x1017, 0x00, 0x8E,  2, (void*)&CO_OD_RAM.producerHeartbeatTime},
{0x1018, 0x04, 0x00,  0, (void*)&OD_record1018},
{0x1019, 0x00, 0x0E,  1, (void*)&CO_OD_RAM.synchronousCounterOverflowValue},
{0x1029, 0x06, 0x06,  0, (void*)&CO_OD_RAM.errorBehavior[0]},
{0x1200, 0x02, 0x00,  0, (void*)&OD_record1200},
{0x1280, 0x03, 0x00,  0, (void*)&OD_record1280},
{0x1400, 0x02, 0x00,  0, (void*)&OD_record1400},
{0x1401, 0x02, 0x00,  0, (void*)&OD_record1401},
{0x1402, 0x02, 0x00,  0, (void*)&OD_record1402},
{0x1403, 0x02, 0x00,  0, (void*)&OD_record1403},
{0x1404, 0x02, 0x00,  0, (void*)&OD_record1404},
{0x1405, 0x02, 0x00,  0, (void*)&OD_record1405},
{0x1406, 0x02, 0x00,  4, (void*)&OD_record1406},
{0x1407, 0x02, 0x00,  4, (void*)&OD_record1407},
{0x1408, 0x02, 0x00,  4, (void*)&OD_record1408},
{0x1409, 0x02, 0x00,  4, (void*)&OD_record1409},
{0x1600, 0x08, 0x00,  0, (void*)&OD_record1600},
{0x1601, 0x08, 0x00,  0, (void*)&OD_record1601},
{0x1602, 0x08, 0x00,  0, (void*)&OD_record1602},
{0x1603, 0x08, 0x00,  0, (void*)&OD_record1603},
{0x1604, 0x08, 0x00,  0, (void*)&OD_record1604},
{0x1605, 0x08, 0x00,  0, (void*)&OD_record1605},
{0x1606, 0x08, 0x00,  4, (void*)&OD_record1606},
{0x1607, 0x08, 0x00,  4, (void*)&OD_record1607},
{0x1608, 0x08, 0x00,  4, (void*)&OD_record1608},
{0x1609, 0x08, 0x00,  4, (void*)&OD_record1609},
{0x1800, 0x06, 0x00,  0, (void*)&OD_record1800},
{0x1801, 0x06, 0x00,  0, (void*)&OD_record1801},
{0x1802, 0x06, 0x00,  0, (void*)&OD_record1802},
{0x1803, 0x06, 0x00,  0, (void*)&OD_record1803},
{0x1804, 0x06, 0x00,  0, (void*)&OD_record1804},
{0x1805, 0x06, 0x00,  0, (void*)&OD_record1805},
{0x1806, 0x06, 0x00,  4, (void*)&OD_record1806},
{0x1807, 0x06, 0x00,  4, (void*)&OD_record1807},
{0x1808, 0x06, 0x00,  4, (void*)&OD_record1808},
{0x1809, 0x06, 0x00,  4, (void*)&OD_record1809},
{0x1A00, 0x08, 0x00,  0, (void*)&OD_record1A00},
{0x1A01, 0x08, 0x00,  0, (void*)&OD_record1A01},
{0x1A02, 0x08, 0x00,  0, (void*)&OD_record1A02},
{0x1A03, 0x08, 0x00,  0, (void*)&OD_record1A03},
{0x1A04, 0x08, 0x00,  0, (void*)&OD_record1A04},
{0x1A05, 0x08, 0x00,  0, (void*)&OD_record1A05},
{0x1A06, 0x08, 0x00,  4, (void*)&OD_record1A06},
{0x1A07, 0x08, 0x00,  4, (void*)&OD_record1A07},
```

```
{0x1A08, 0x08, 0x00,  4, (void*)&OD_record1A08},
{0x1A09, 0x08, 0x00,  4, (void*)&OD_record1A09},
{0x1F80, 0x00, 0x8E,  4, (void*)&CO_OD_RAM.NMTStartup},
{0x2100, 0x00, 0x26, 10, (void*)&CO_OD_RAM.errorStatusBits},
{0x2101, 0x00, 0x0E,  1, (void*)&CO_OD_RAM.CANNodeID},
{0x2102, 0x00, 0x8E,  2, (void*)&CO_OD_RAM.CANBitRate},
{0x2103, 0x00, 0x8E,  2, (void*)&CO_OD_RAM.SYNCCounter},
{0x2104, 0x00, 0x86,  2, (void*)&CO_OD_RAM.SYNCTime},
{0x2106, 0x00, 0x86,  4, (void*)&CO_OD_RAM.powerOnCounter},
{0x2107, 0x05, 0x06,  0, (void*)&CO_OD_RAM.performance[0]},
{0x2108, 0x01, 0x06,  0, (void*)&CO_OD_RAM.temperature[0]},
{0x2109, 0x01, 0x06,  0, (void*)&CO_OD_RAM.voltage[0]},
{0x2110, 0x10, 0x06,  0, (void*)&CO_OD_RAM.variableInt32[0]},
{0x2111, 0x10, 0x06,  0, (void*)&CO_OD_RAM.variableROM_Int32[0]},
{0x2112, 0x10, 0x06,  0, (void*)&CO_OD_RAM.variableNV_Int32[0]},
{0x2120, 0x05, 0x00,  0, (void*)&OD_record2120},
{0x2130, 0x03, 0x00,  0, (void*)&OD_record2130},
{0x2301, 0x08, 0x00,  0, (void*)&OD_record2301},
{0x2302, 0x08, 0x00,  0, (void*)&OD_record2302},
{0x2400, 0x00, 0x1E,  1, (void*)&CO_OD_RAM.traceEnable},
{0x2401, 0x06, 0x00,  0, (void*)&OD_record2401},
{0x2402, 0x06, 0x00,  0, (void*)&OD_record2402},
{0x6010, 0x00, 0xFE,  2, (void*)&CO_OD_RAM.IGUS_D1Controlword1},
{0x6011, 0x00, 0xBE,  2, (void*)&CO_OD_RAM.IGUS_D1Statusword1},
{0x6012, 0x00, 0xBE,  4, (void*)&CO_OD_RAM.IGUS_D1PositionActualValue1},
{0x6013, 0x00, 0xBE,  4, (void*)&CO_OD_RAM.IGUS_D1VelocityActualValue1},
{0x6014, 0x00, 0xFE,  4, (void*)&CO_OD_RAM.IGUS_D1TargetPosition1},
{0x6015, 0x00, 0xBE,  4, (void*)&CO_OD_RAM.IGUS_D1TargetVelocity1},
{0x6020, 0x00, 0xFE,  2, (void*)&CO_OD_RAM.IGUS_D1Controlword2},
{0x6021, 0x00, 0xBE,  2, (void*)&CO_OD_RAM.IGUS_D1Statusword2},
{0x6022, 0x00, 0xBE,  4, (void*)&CO_OD_RAM.IGUS_D1PositionActualValue2},
{0x6023, 0x00, 0xBE,  4, (void*)&CO_OD_RAM.IGUS_D1VelocityActualValue2},
{0x6024, 0x00, 0xFE,  4, (void*)&CO_OD_RAM.IGUS_D1TargetPosition2},
{0x6025, 0x00, 0xBE,  4, (void*)&CO_OD_RAM.IGUS_D1TargetVelocity2},
{0x6030, 0x00, 0xFE,  2, (void*)&CO_OD_RAM.IGUS_D1Controlword3},
{0x6031, 0x00, 0xBE,  2, (void*)&CO_OD_RAM.IGUS_D1Statusword3},
{0x6032, 0x00, 0xBE,  4, (void*)&CO_OD_RAM.IGUS_D1PositionActualValue3},
{0x6033, 0x00, 0xBE,  4, (void*)&CO_OD_RAM.IGUS_D1VelocityActualValue3},
{0x6034, 0x00, 0xFE,  4, (void*)&CO_OD_RAM.IGUS_D1TargetPosition3},
{0x6035, 0x00, 0xBE,  4, (void*)&CO_OD_RAM.IGUS_D1TargetVelocity3},
{0x6040, 0x00, 0xFE,  2, (void*)&CO_OD_RAM.IGUS_D1Controlword4},
{0x6041, 0x00, 0xBE,  2, (void*)&CO_OD_RAM.IGUS_D1Statusword4},
{0x6042, 0x00, 0xBE,  4, (void*)&CO_OD_RAM.IGUS_D1PositionActualValue4},
{0x6043, 0x00, 0xBE,  4, (void*)&CO_OD_RAM.IGUS_D1VelocityActualValue4},
{0x6044, 0x00, 0xFE,  4, (void*)&CO_OD_RAM.IGUS_D1TargetPosition4},
{0x6045, 0x00, 0xBE,  4, (void*)&CO_OD_RAM.IGUS_D1TargetVelocity4},
{0x6050, 0x00, 0xFE,  2, (void*)&CO_OD_RAM.IGUS_D1Controlword5},
{0x6051, 0x00, 0xBE,  2, (void*)&CO_OD_RAM.IGUS_D1Statusword5},
{0x6052, 0x00, 0xBE,  4, (void*)&CO_OD_RAM.IGUS_D1PositionActualValue5},
{0x6053, 0x00, 0xBE,  4, (void*)&CO_OD_RAM.IGUS_D1VelocityActualValue5},
{0x6054, 0x00, 0xFE,  4, (void*)&CO_OD_RAM.IGUS_D1TargetPosition5},
{0x6055, 0x00, 0xBE,  4, (void*)&CO_OD_RAM.IGUS_D1TargetVelocity5},
{0x6060, 0x00, 0xFE,  2, (void*)&CO_OD_RAM.IGUS_D1Controlword6},
{0x6061, 0x00, 0xBE,  2, (void*)&CO_OD_RAM.IGUS_D1Statusword6},
{0x6062, 0x00, 0xBE,  4, (void*)&CO_OD_RAM.IGUS_D1PositionActualValue6},
{0x6063, 0x00, 0xBE,  4, (void*)&CO_OD_RAM.IGUS_D1VelocityActualValue6},
{0x6064, 0x00, 0xFE,  4, (void*)&CO_OD_RAM.IGUS_D1TargetPosition6},
{0x6065, 0x00, 0xBE,  4, (void*)&CO_OD_RAM.IGUS_D1TargetVelocity6},
{0x60A0, 0x00, 0xFE,  2, (void*)&CO_OD_RAM.motorControlword1},
{0x60A1, 0x00, 0xBE,  2, (void*)&CO_OD_RAM.motorStatusword1},
{0x60A2, 0x00, 0xFE,  2, (void*)&CO_OD_RAM.motorTargetVelocity1},
{0x60A3, 0x00, 0xBE,  2, (void*)&CO_OD_RAM.motorActualVelocity1},
{0x60B0, 0x00, 0xFE,  2, (void*)&CO_OD_RAM.motorControlword2},
{0x60B1, 0x00, 0xBE,  2, (void*)&CO_OD_RAM.motorStatusword2},
```

```
{0x60B2, 0x00, 0xFE,  2, (void*)&CO_OD_RAM.motorTargetVelocity2},
{0x60B3, 0x00, 0xBE,  2, (void*)&CO_OD_RAM.motorActualVelocity2},
{0x60C0, 0x00, 0xFE,  2, (void*)&CO_OD_RAM.motorControlword3},
{0x60C1, 0x00, 0xBE,  2, (void*)&CO_OD_RAM.motorStatusword3},
{0x60C2, 0x00, 0xFE,  2, (void*)&CO_OD_RAM.motorTargetVelocity3},
{0x60C3, 0x00, 0xBE,  2, (void*)&CO_OD_RAM.motorActualVelocity3},
{0x60D0, 0x00, 0xFE,  2, (void*)&CO_OD_RAM.motorControlword4},
{0x60D1, 0x00, 0xBE,  2, (void*)&CO_OD_RAM.motorStatusword4},
{0x60D2, 0x00, 0xFE,  2, (void*)&CO_OD_RAM.motorTargetVelocity4},
{0x60D3, 0x00, 0xBE,  2, (void*)&CO_OD_RAM.motorActualVelocity4},
};
// clang-format on
```

Fails “CO_OD.h”

```
// clang-format off
/*******************************************************************************

   File - CO_OD.c/CO_OD.h
   CANopen Object Dictionary.

   This file was automatically generated with libedssharp Object
   Dictionary Editor vUnknown   DON'T EDIT THIS FILE MANUALLY !!!!
*******************************************************************************/


#ifndef CO_OD_H_
#define CO_OD_H_

/*******************************************************************************
   CANopen DATA TYPES
*******************************************************************************/
   typedef bool_t       BOOLEAN;
   typedef uint8_t      UNSIGNED8;
   typedef uint16_t     UNSIGNED16;
   typedef uint32_t     UNSIGNED32;
   typedef uint64_t     UNSIGNED64;
   typedef int8_t       INTEGER8;
   typedef int16_t      INTEGER16;
   typedef int32_t      INTEGER32;
   typedef int64_t      INTEGER64;
   typedef float32_t    REAL32;
   typedef float64_t    REAL64;
   typedef char_t       VISIBLE_STRING;
   typedef oChar_t      OCTET_STRING;

   #ifdef DOMAIN
   #undef DOMAIN
   #endif

   typedef domain_t     DOMAIN;

#ifndef timeOfDay_t
    typedef union {
        unsigned long long ullValue;
        struct {
            unsigned long ms:28;
            unsigned reserved:4;
            unsigned days:16;
            unsigned reserved2:16;
        };
    }timeOfDay_t;
#endif

    typedef timeOfDay_t TIME_OF_DAY;
    typedef timeOfDay_t TIME_DIFFERENCE;


/*******************************************************************************
   FILE INFO:
      FileName:
      FileVersion:  0
      CreationTime: 5:01pēcp.
      CreationDate: 08-29-2018
      CreatedBy:    Vitalijs
*******************************************************************************/
```

```
/*******************************************************************************
   DEVICE INFO:
      VendorName:     Mitavas_roboti
      VendorNumber:   0
      ProductName:    RONINMainController
      ProductNumber:  0
*******************************************************************************/


/*******************************************************************************
   FEATURES
*******************************************************************************/
  #define CO_NO_SYNC                     0   //Associated objects: 1005-1007
  #define CO_NO_EMERGENCY                1   //Associated objects: 1014, 1015
  #define CO_NO_TIME                     0   //Associated objects: 1012, 1013
  #define CO_NO_SDO_SERVER               1   //Associated objects: 1200-127F
  #define CO_NO_SDO_CLIENT               1   //Associated objects: 1280-12FF
  #define CO_NO_LSS_SERVER               0   //LSS Slave
  #define CO_NO_LSS_CLIENT               0   //LSS Master
  #define CO_NO_GFC                     0
  #define CO_NO_SRDO                     0
  #define CO_NO_RPDO                     10   //Associated objects: 14xx, 16xx
  #define CO_NO_TPDO                     10   //Associated objects: 18xx, 1Axx
  #define CO_NO_NMT_MASTER               1
  #define CO_NO_TRACE                    0


/*******************************************************************************
   OBJECT DICTIONARY
*******************************************************************************/
   #define CO_OD_NoOfElements             133


/*******************************************************************************
   TYPE DEFINITIONS FOR RECORDS
*******************************************************************************/
/*1018      */ typedef struct {
               UNSIGNED8      maxSubIndex;
               UNSIGNED32     vendorID;
               UNSIGNED32     productCode;
               UNSIGNED32     revisionNumber;
               UNSIGNED32     serialNumber;
               }              OD_identity_t;
/*1200      */ typedef struct {
               UNSIGNED8      maxSubIndex;
               UNSIGNED32     COB_IDClientToServer;
               UNSIGNED32     COB_IDServerToClient;
               }              OD_SDOServerParameter_t;
/*1280      */ typedef struct {
               UNSIGNED8      maxSubIndex;
               UNSIGNED32     COB_IDClientToServer;
               UNSIGNED32     COB_IDServerToClient;
               UNSIGNED8      nodeIDOfTheSDOServer;
               }              OD_SDOClientParameter_t;
/*1400      */ typedef struct {
               UNSIGNED8      maxSubIndex;
               UNSIGNED32     COB_IDUsedByRPDO;
               UNSIGNED8      transmissionType;
               }              OD_RPDOCommunicationParameter_t;
/*1600      */ typedef struct {
               UNSIGNED8      numberOfMappedObjects;
               UNSIGNED32     mappedObject1;
               UNSIGNED32     mappedObject2;
```

```
                 UNSIGNED32     mappedObject3;
                 UNSIGNED32     mappedObject4;
                 UNSIGNED32     mappedObject5;
                 UNSIGNED32     mappedObject6;
                 UNSIGNED32     mappedObject7;
                 UNSIGNED32     mappedObject8;
                 }              OD_RPDOMappingParameter_t;
/*1800      */ typedef struct {
                 UNSIGNED8      maxSubIndex;
                 UNSIGNED32     COB_IDUsedByTPDO;
                 UNSIGNED8      transmissionType;
                 UNSIGNED16     inhibitTime;
                 UNSIGNED8      compatibilityEntry;
                 UNSIGNED16     eventTimer;
                 UNSIGNED8      SYNCStartValue;
                 }              OD_TPDOCommunicationParameter_t;
/*1A00      */ typedef struct {
                 UNSIGNED8      numberOfMappedObjects;
                 UNSIGNED32     mappedObject1;
                 UNSIGNED32     mappedObject2;
                 UNSIGNED32     mappedObject3;
                 UNSIGNED32     mappedObject4;
                 UNSIGNED32     mappedObject5;
                 UNSIGNED32     mappedObject6;
                 UNSIGNED32     mappedObject7;
                 UNSIGNED32     mappedObject8;
                 }              OD_TPDOMappingParameter_t;
/*2120      */ typedef struct {
                 UNSIGNED8      maxSubIndex;
                 INTEGER64      I64;
                 UNSIGNED64     U64;
                 REAL32         R32;
                 REAL64         R64;
                 DOMAIN         domain;
                 }              OD_testVar_t;
/*2130      */ typedef struct {
                 UNSIGNED8      maxSubIndex;
                 VISIBLE_STRING string[1];
                 UNSIGNED64     epochTimeBaseMs;
                 UNSIGNED32     epochTimeOffsetMs;
                 }              OD_time_t;
/*2301      */ typedef struct {
                 UNSIGNED8      maxSubIndex;
                 UNSIGNED32     size;
                 UNSIGNED8      axisNo;
                 VISIBLE_STRING name[6];
                 VISIBLE_STRING color[3];
                 UNSIGNED32     map;
                 UNSIGNED8      format;
                 UNSIGNED8      trigger;
                 INTEGER32      threshold;
                 }              OD_traceConfig_t;
/*2401      */ typedef struct {
                 UNSIGNED8      maxSubIndex;
                 UNSIGNED32     size;
                 INTEGER32      value;
                 INTEGER32      min;
                 INTEGER32      max;
                 DOMAIN         plot;
                 UNSIGNED32     triggerTime;
                 }              OD_trace_t;

/*******************************************************************************
   TYPE DEFINITIONS FOR OBJECT DICTIONARY INDEXES
```

```
   some of those are redundant with CO_SDO.h CO_ObjDicId_t <Common CiA301 object
   dictionary entries>
*******************************************************************************/
/*0005 */
        #define OD_0005_compatabilityEntry                          0x0005

/*1000 */
        #define OD_1000_deviceType                                  0x1000

/*1001 */
        #define OD_1001_errorRegister                               0x1001

/*1002 */
        #define OD_1002_manufacturerStatusRegister                  0x1002

/*1003 */
        #define OD_1003_preDefinedErrorField                        0x1003

        #define OD_1003_0_preDefinedErrorField_maxSubIndex          0
        #define OD_1003_1_preDefinedErrorField_standardErrorField   1
        #define OD_1003_2_preDefinedErrorField_standardErrorField   2
        #define OD_1003_3_preDefinedErrorField_standardErrorField   3
        #define OD_1003_4_preDefinedErrorField_standardErrorField   4
        #define OD_1003_5_preDefinedErrorField_standardErrorField   5
        #define OD_1003_6_preDefinedErrorField_standardErrorField   6
        #define OD_1003_7_preDefinedErrorField_standardErrorField   7
        #define OD_1003_8_preDefinedErrorField_standardErrorField   8

/*1006 */
        #define OD_1006_communicationCyclePeriod                    0x1006

/*1007 */
        #define OD_1007_synchronousWindowLength                     0x1007

/*1008 */
        #define OD_1008_manufacturerDeviceName                      0x1008

/*1009 */
        #define OD_1009_manufacturerHardwareVersion                 0x1009

/*100A */
        #define OD_100A_manufacturerSoftwareVersion                 0x100A

/*1010 */
        #define OD_1010_storeParameters                             0x1010

        #define OD_1010_0_storeParameters_maxSubIndex               0
        #define OD_1010_1_storeParameters_saveAllParameters         1

/*1011 */
        #define OD_1011_restoreDefaultParameters                    0x1011

        #define OD_1011_0_restoreDefaultParameters_maxSubIndex      0
        #define OD_1011_1_restoreDefaultParameters_restoreAllDefaultParameters 1

/*1014 */
        #define OD_1014_COB_ID_EMCY                                 0x1014

/*1015 */
        #define OD_1015_inhibitTimeEMCY                             0x1015

/*1016 */
        #define OD_1016_consumerHeartbeatTime                       0x1016
```

```
        #define OD_1016_0_consumerHeartbeatTime_maxSubIndex         0
        #define OD_1016_1_consumerHeartbeatTime_consumerHeartbeatTime 1
        #define OD_1016_2_consumerHeartbeatTime_consumerHeartbeatTime 2
        #define OD_1016_3_consumerHeartbeatTime_consumerHeartbeatTime 3
        #define OD_1016_4_consumerHeartbeatTime_consumerHeartbeatTime 4

/*1017 */
        #define OD_1017_producerHeartbeatTime                       0x1017

/*1018 */
        #define OD_1018_identity                                    0x1018

        #define OD_1018_0_identity_maxSubIndex                      0
        #define OD_1018_1_identity_vendorID                         1
        #define OD_1018_2_identity_productCode                      2
        #define OD_1018_3_identity_revisionNumber                   3
        #define OD_1018_4_identity_serialNumber                     4

/*1019 */
        #define OD_1019_synchronousCounterOverflowValue             0x1019

/*1029 */
        #define OD_1029_errorBehavior                               0x1029

        #define OD_1029_0_errorBehavior_maxSubIndex                 0
        #define OD_1029_1_errorBehavior_communication               1
        #define OD_1029_2_errorBehavior_communicationOther          2
        #define OD_1029_3_errorBehavior_communicationPassive        3
        #define OD_1029_4_errorBehavior_generic                     4
        #define OD_1029_5_errorBehavior_deviceProfile               5
        #define OD_1029_6_errorBehavior_manufacturerSpecific        6

/*1200 */
        #define OD_1200_SDOServerParameter                          0x1200

        #define OD_1200_0_SDOServerParameter_maxSubIndex            0
        #define OD_1200_1_SDOServerParameter_COB_IDClientToServer   1
        #define OD_1200_2_SDOServerParameter_COB_IDServerToClient   2

/*1280 */
        #define OD_1280_SDOClientParameter                          0x1280

        #define OD_1280_0_SDOClientParameter_maxSubIndex            0
        #define OD_1280_1_SDOClientParameter_COB_IDClientToServer   1
        #define OD_1280_2_SDOClientParameter_COB_IDServerToClient   2
        #define OD_1280_3_SDOClientParameter_nodeIDOfTheSDOServer   3

/*1400 */
        #define OD_1400_RPDOCommunicationParameter                  0x1400

        #define OD_1400_0_RPDOCommunicationParameter_maxSubIndex    0
        #define OD_1400_1_RPDOCommunicationParameter_COB_IDUsedByRPDO 1
        #define OD_1400_2_RPDOCommunicationParameter_transmissionType 2

/*1401 */
        #define OD_1401_RPDOCommunicationParameter                  0x1401

        #define OD_1401_0_RPDOCommunicationParameter_maxSubIndex    0
        #define OD_1401_1_RPDOCommunicationParameter_COB_IDUsedByRPDO 1
        #define OD_1401_2_RPDOCommunicationParameter_transmissionType 2

/*1402 */
        #define OD_1402_RPDOCommunicationParameter                  0x1402
```

```
        #define OD_1402_0_RPDOCommunicationParameter_maxSubIndex    0
        #define OD_1402_1_RPDOCommunicationParameter_COB_IDUsedByRPDO 1
        #define OD_1402_2_RPDOCommunicationParameter_transmissionType 2

/*1403 */
        #define OD_1403_RPDOCommunicationParameter                  0x1403

        #define OD_1403_0_RPDOCommunicationParameter_maxSubIndex    0
        #define OD_1403_1_RPDOCommunicationParameter_COB_IDUsedByRPDO 1
        #define OD_1403_2_RPDOCommunicationParameter_transmissionType 2

/*1404 */
        #define OD_1404_RPDOCommunicationParameter                  0x1404

        #define OD_1404_0_RPDOCommunicationParameter_maxSubIndex    0
        #define OD_1404_1_RPDOCommunicationParameter_COB_IDUsedByRPDO 1
        #define OD_1404_2_RPDOCommunicationParameter_transmissionType 2

/*1405 */
        #define OD_1405_RPDOCommunicationParameter                  0x1405

        #define OD_1405_0_RPDOCommunicationParameter_maxSubIndex    0
        #define OD_1405_1_RPDOCommunicationParameter_COB_IDUsedByRPDO 1
        #define OD_1405_2_RPDOCommunicationParameter_transmissionType 2

/*1406 */
        #define OD_1406_RPDOCommunicationParameter                  0x1406

        #define OD_1406_0_RPDOCommunicationParameter_maxSubIndex    0
        #define OD_1406_1_RPDOCommunicationParameter_COB_IDUsedByRPDO 1
        #define OD_1406_2_RPDOCommunicationParameter_transmissionType 2

/*1407 */
        #define OD_1407_RPDOCommunicationParameter                  0x1407

        #define OD_1407_0_RPDOCommunicationParameter_maxSubIndex    0
        #define OD_1407_1_RPDOCommunicationParameter_COB_IDUsedByRPDO 1
        #define OD_1407_2_RPDOCommunicationParameter_transmissionType 2

/*1408 */
        #define OD_1408_RPDOCommunicationParameter                  0x1408

        #define OD_1408_0_RPDOCommunicationParameter_maxSubIndex    0
        #define OD_1408_1_RPDOCommunicationParameter_COB_IDUsedByRPDO 1
        #define OD_1408_2_RPDOCommunicationParameter_transmissionType 2

/*1409 */
        #define OD_1409_RPDOCommunicationParameter                  0x1409

        #define OD_1409_0_RPDOCommunicationParameter_maxSubIndex    0
        #define OD_1409_1_RPDOCommunicationParameter_COB_IDUsedByRPDO 1
        #define OD_1409_2_RPDOCommunicationParameter_transmissionType 2

/*1600 */
        #define OD_1600_RPDOMappingParameter                        0x1600

        #define OD_1600_0_RPDOMappingParameter_maxSubIndex          0
        #define OD_1600_1_RPDOMappingParameter_mappedObject1        1
        #define OD_1600_2_RPDOMappingParameter_mappedObject2        2
        #define OD_1600_3_RPDOMappingParameter_mappedObject3        3
        #define OD_1600_4_RPDOMappingParameter_mappedObject4        4
        #define OD_1600_5_RPDOMappingParameter_mappedObject5        5
        #define OD_1600_6_RPDOMappingParameter_mappedObject6        6
```

```
        #define OD_1600_7_RPDOMappingParameter_mappedObject7        7
        #define OD_1600_8_RPDOMappingParameter_mappedObject8        8

/*1601 */
        #define OD_1601_RPDOMappingParameter                        0x1601

        #define OD_1601_0_RPDOMappingParameter_maxSubIndex          0
        #define OD_1601_1_RPDOMappingParameter_mappedObject1        1
        #define OD_1601_2_RPDOMappingParameter_mappedObject2        2
        #define OD_1601_3_RPDOMappingParameter_mappedObject3        3
        #define OD_1601_4_RPDOMappingParameter_mappedObject4        4
        #define OD_1601_5_RPDOMappingParameter_mappedObject5        5
        #define OD_1601_6_RPDOMappingParameter_mappedObject6        6
        #define OD_1601_7_RPDOMappingParameter_mappedObject7        7
        #define OD_1601_8_RPDOMappingParameter_mappedObject8        8

/*1602 */
        #define OD_1602_RPDOMappingParameter                        0x1602

        #define OD_1602_0_RPDOMappingParameter_maxSubIndex          0
        #define OD_1602_1_RPDOMappingParameter_mappedObject1        1
        #define OD_1602_2_RPDOMappingParameter_mappedObject2        2
        #define OD_1602_3_RPDOMappingParameter_mappedObject3        3
        #define OD_1602_4_RPDOMappingParameter_mappedObject4        4
        #define OD_1602_5_RPDOMappingParameter_mappedObject5        5
        #define OD_1602_6_RPDOMappingParameter_mappedObject6        6
        #define OD_1602_7_RPDOMappingParameter_mappedObject7        7
        #define OD_1602_8_RPDOMappingParameter_mappedObject8        8

/*1603 */
        #define OD_1603_RPDOMappingParameter                        0x1603

        #define OD_1603_0_RPDOMappingParameter_maxSubIndex          0
        #define OD_1603_1_RPDOMappingParameter_mappedObject1        1
        #define OD_1603_2_RPDOMappingParameter_mappedObject2        2
        #define OD_1603_3_RPDOMappingParameter_mappedObject3        3
        #define OD_1603_4_RPDOMappingParameter_mappedObject4        4
        #define OD_1603_5_RPDOMappingParameter_mappedObject5        5
        #define OD_1603_6_RPDOMappingParameter_mappedObject6        6
        #define OD_1603_7_RPDOMappingParameter_mappedObject7        7
        #define OD_1603_8_RPDOMappingParameter_mappedObject8        8

/*1604 */
        #define OD_1604_RPDOMappingParameter                        0x1604

        #define OD_1604_0_RPDOMappingParameter_maxSubIndex          0
        #define OD_1604_1_RPDOMappingParameter_mappedObject1        1
        #define OD_1604_2_RPDOMappingParameter_mappedObject2        2
        #define OD_1604_3_RPDOMappingParameter_mappedObject3        3
        #define OD_1604_4_RPDOMappingParameter_mappedObject4        4
        #define OD_1604_5_RPDOMappingParameter_mappedObject5        5
        #define OD_1604_6_RPDOMappingParameter_mappedObject6        6
        #define OD_1604_7_RPDOMappingParameter_mappedObject7        7
        #define OD_1604_8_RPDOMappingParameter_mappedObject8        8

/*1605 */
        #define OD_1605_RPDOMappingParameter                        0x1605

        #define OD_1605_0_RPDOMappingParameter_maxSubIndex          0
        #define OD_1605_1_RPDOMappingParameter_mappedObject1        1
        #define OD_1605_2_RPDOMappingParameter_mappedObject2        2
        #define OD_1605_3_RPDOMappingParameter_mappedObject3        3
        #define OD_1605_4_RPDOMappingParameter_mappedObject4        4
        #define OD_1605_5_RPDOMappingParameter_mappedObject5        5
```

```
        #define OD_1605_6_RPDOMappingParameter_mappedObject6        6
        #define OD_1605_7_RPDOMappingParameter_mappedObject7        7
        #define OD_1605_8_RPDOMappingParameter_mappedObject8        8

/*1606 */
        #define OD_1606_RPDOMappingParameter                        0x1606

        #define OD_1606_0_RPDOMappingParameter_maxSubIndex          0
        #define OD_1606_1_RPDOMappingParameter_mappedObject1        1
        #define OD_1606_2_RPDOMappingParameter_mappedObject2        2
        #define OD_1606_3_RPDOMappingParameter_mappedObject3        3
        #define OD_1606_4_RPDOMappingParameter_mappedObject4        4
        #define OD_1606_5_RPDOMappingParameter_mappedObject5        5
        #define OD_1606_6_RPDOMappingParameter_mappedObject6        6
        #define OD_1606_7_RPDOMappingParameter_mappedObject7        7
        #define OD_1606_8_RPDOMappingParameter_mappedObject8        8

/*1607 */
        #define OD_1607_RPDOMappingParameter                        0x1607

        #define OD_1607_0_RPDOMappingParameter_maxSubIndex          0
        #define OD_1607_1_RPDOMappingParameter_mappedObject1        1
        #define OD_1607_2_RPDOMappingParameter_mappedObject2        2
        #define OD_1607_3_RPDOMappingParameter_mappedObject3        3
        #define OD_1607_4_RPDOMappingParameter_mappedObject4        4
        #define OD_1607_5_RPDOMappingParameter_mappedObject5        5
        #define OD_1607_6_RPDOMappingParameter_mappedObject6        6
        #define OD_1607_7_RPDOMappingParameter_mappedObject7        7
        #define OD_1607_8_RPDOMappingParameter_mappedObject8        8

/*1608 */
        #define OD_1608_RPDOMappingParameter                        0x1608

        #define OD_1608_0_RPDOMappingParameter_maxSubIndex          0
        #define OD_1608_1_RPDOMappingParameter_mappedObject1        1
        #define OD_1608_2_RPDOMappingParameter_mappedObject2        2
        #define OD_1608_3_RPDOMappingParameter_mappedObject3        3
        #define OD_1608_4_RPDOMappingParameter_mappedObject4        4
        #define OD_1608_5_RPDOMappingParameter_mappedObject5        5
        #define OD_1608_6_RPDOMappingParameter_mappedObject6        6
        #define OD_1608_7_RPDOMappingParameter_mappedObject7        7
        #define OD_1608_8_RPDOMappingParameter_mappedObject8        8

/*1609 */
        #define OD_1609_RPDOMappingParameter                        0x1609

        #define OD_1609_0_RPDOMappingParameter_maxSubIndex          0
        #define OD_1609_1_RPDOMappingParameter_mappedObject1        1
        #define OD_1609_2_RPDOMappingParameter_mappedObject2        2
        #define OD_1609_3_RPDOMappingParameter_mappedObject3        3
        #define OD_1609_4_RPDOMappingParameter_mappedObject4        4
        #define OD_1609_5_RPDOMappingParameter_mappedObject5        5
        #define OD_1609_6_RPDOMappingParameter_mappedObject6        6
        #define OD_1609_7_RPDOMappingParameter_mappedObject7        7
        #define OD_1609_8_RPDOMappingParameter_mappedObject8        8

/*1800 */
        #define OD_1800_TPDOCommunicationParameter                  0x1800

        #define OD_1800_0_TPDOCommunicationParameter_maxSubIndex    0
        #define OD_1800_1_TPDOCommunicationParameter_COB_IDUsedByTPDO 1
        #define OD_1800_2_TPDOCommunicationParameter_transmissionType 2
        #define OD_1800_3_TPDOCommunicationParameter_inhibitTime    3
        #define OD_1800_4_TPDOCommunicationParameter_compatibilityEntry 4
```

```
        #define OD_1800_5_TPDOCommunicationParameter_eventTimer     5
        #define OD_1800_6_TPDOCommunicationParameter_SYNCStartValue 6

/*1801 */
        #define OD_1801_TPDOCommunicationParameter                  0x1801

        #define OD_1801_0_TPDOCommunicationParameter_maxSubIndex    0
        #define OD_1801_1_TPDOCommunicationParameter_COB_IDUsedByTPDO 1
        #define OD_1801_2_TPDOCommunicationParameter_transmissionType 2
        #define OD_1801_3_TPDOCommunicationParameter_inhibitTime    3
        #define OD_1801_4_TPDOCommunicationParameter_compatibilityEntry 4
        #define OD_1801_5_TPDOCommunicationParameter_eventTimer     5
        #define OD_1801_6_TPDOCommunicationParameter_SYNCStartValue 6

/*1802 */
        #define OD_1802_TPDOCommunicationParameter                  0x1802

        #define OD_1802_0_TPDOCommunicationParameter_maxSubIndex    0
        #define OD_1802_1_TPDOCommunicationParameter_COB_IDUsedByTPDO 1
        #define OD_1802_2_TPDOCommunicationParameter_transmissionType 2
        #define OD_1802_3_TPDOCommunicationParameter_inhibitTime    3
        #define OD_1802_4_TPDOCommunicationParameter_compatibilityEntry 4
        #define OD_1802_5_TPDOCommunicationParameter_eventTimer     5
        #define OD_1802_6_TPDOCommunicationParameter_SYNCStartValue 6

/*1803 */
        #define OD_1803_TPDOCommunicationParameter                  0x1803

        #define OD_1803_0_TPDOCommunicationParameter_maxSubIndex    0
        #define OD_1803_1_TPDOCommunicationParameter_COB_IDUsedByTPDO 1
        #define OD_1803_2_TPDOCommunicationParameter_transmissionType 2
        #define OD_1803_3_TPDOCommunicationParameter_inhibitTime    3
        #define OD_1803_4_TPDOCommunicationParameter_compatibilityEntry 4
        #define OD_1803_5_TPDOCommunicationParameter_eventTimer     5
        #define OD_1803_6_TPDOCommunicationParameter_SYNCStartValue 6

/*1804 */
        #define OD_1804_TPDOCommunicationParameter                  0x1804

        #define OD_1804_0_TPDOCommunicationParameter_maxSubIndex    0
        #define OD_1804_1_TPDOCommunicationParameter_COB_IDUsedByTPDO 1
        #define OD_1804_2_TPDOCommunicationParameter_transmissionType 2
        #define OD_1804_3_TPDOCommunicationParameter_inhibitTime    3
        #define OD_1804_4_TPDOCommunicationParameter_compatibilityEntry 4
        #define OD_1804_5_TPDOCommunicationParameter_eventTimer     5
        #define OD_1804_6_TPDOCommunicationParameter_SYNCStartValue 6

/*1805 */
        #define OD_1805_TPDOCommunicationParameter                  0x1805

        #define OD_1805_0_TPDOCommunicationParameter_maxSubIndex    0
        #define OD_1805_1_TPDOCommunicationParameter_COB_IDUsedByTPDO 1
        #define OD_1805_2_TPDOCommunicationParameter_transmissionType 2
        #define OD_1805_3_TPDOCommunicationParameter_inhibitTime    3
        #define OD_1805_4_TPDOCommunicationParameter_compatibilityEntry 4
        #define OD_1805_5_TPDOCommunicationParameter_eventTimer     5
        #define OD_1805_6_TPDOCommunicationParameter_SYNCStartValue 6

/*1806 */
        #define OD_1806_TPDOCommunicationParameter                  0x1806

        #define OD_1806_0_TPDOCommunicationParameter_maxSubIndex    0
        #define OD_1806_1_TPDOCommunicationParameter_COB_IDUsedByTPDO 1
        #define OD_1806_2_TPDOCommunicationParameter_transmissionType 2
```

```
        #define OD_1806_3_TPDOCommunicationParameter_inhibitTime    3
        #define OD_1806_4_TPDOCommunicationParameter_compatibilityEntry 4
        #define OD_1806_5_TPDOCommunicationParameter_eventTimer     5
        #define OD_1806_6_TPDOCommunicationParameter_SYNCStartValue 6

/*1807 */
        #define OD_1807_TPDOCommunicationParameter                  0x1807

        #define OD_1807_0_TPDOCommunicationParameter_maxSubIndex    0
        #define OD_1807_1_TPDOCommunicationParameter_COB_IDUsedByTPDO 1
        #define OD_1807_2_TPDOCommunicationParameter_transmissionType 2
        #define OD_1807_3_TPDOCommunicationParameter_inhibitTime    3
        #define OD_1807_4_TPDOCommunicationParameter_compatibilityEntry 4
        #define OD_1807_5_TPDOCommunicationParameter_eventTimer     5
        #define OD_1807_6_TPDOCommunicationParameter_SYNCStartValue 6

/*1808 */
        #define OD_1808_TPDOCommunicationParameter                  0x1808

        #define OD_1808_0_TPDOCommunicationParameter_maxSubIndex    0
        #define OD_1808_1_TPDOCommunicationParameter_COB_IDUsedByTPDO 1
        #define OD_1808_2_TPDOCommunicationParameter_transmissionType 2
        #define OD_1808_3_TPDOCommunicationParameter_inhibitTime    3
        #define OD_1808_4_TPDOCommunicationParameter_compatibilityEntry 4
        #define OD_1808_5_TPDOCommunicationParameter_eventTimer     5
        #define OD_1808_6_TPDOCommunicationParameter_SYNCStartValue 6

/*1809 */
        #define OD_1809_TPDOCommunicationParameter                  0x1809

        #define OD_1809_0_TPDOCommunicationParameter_maxSubIndex    0
        #define OD_1809_1_TPDOCommunicationParameter_COB_IDUsedByTPDO 1
        #define OD_1809_2_TPDOCommunicationParameter_transmissionType 2
        #define OD_1809_3_TPDOCommunicationParameter_inhibitTime    3
        #define OD_1809_4_TPDOCommunicationParameter_compatibilityEntry 4
        #define OD_1809_5_TPDOCommunicationParameter_eventTimer     5
        #define OD_1809_6_TPDOCommunicationParameter_SYNCStartValue 6

/*1A00 */
        #define OD_1A00_TPDOMappingParameter                        0x1A00

        #define OD_1A00_0_TPDOMappingParameter_maxSubIndex          0
        #define OD_1A00_1_TPDOMappingParameter_mappedObject1        1
        #define OD_1A00_2_TPDOMappingParameter_mappedObject2        2
        #define OD_1A00_3_TPDOMappingParameter_mappedObject3        3
        #define OD_1A00_4_TPDOMappingParameter_mappedObject4        4
        #define OD_1A00_5_TPDOMappingParameter_mappedObject5        5
        #define OD_1A00_6_TPDOMappingParameter_mappedObject6        6
        #define OD_1A00_7_TPDOMappingParameter_mappedObject7        7
        #define OD_1A00_8_TPDOMappingParameter_mappedObject8        8

/*1A01 */
        #define OD_1A01_TPDOMappingParameter                        0x1A01

        #define OD_1A01_0_TPDOMappingParameter_maxSubIndex          0
        #define OD_1A01_1_TPDOMappingParameter_mappedObject1        1
        #define OD_1A01_2_TPDOMappingParameter_mappedObject2        2
        #define OD_1A01_3_TPDOMappingParameter_mappedObject3        3
        #define OD_1A01_4_TPDOMappingParameter_mappedObject4        4
        #define OD_1A01_5_TPDOMappingParameter_mappedObject5        5
        #define OD_1A01_6_TPDOMappingParameter_mappedObject6        6
        #define OD_1A01_7_TPDOMappingParameter_mappedObject7        7
        #define OD_1A01_8_TPDOMappingParameter_mappedObject8        8
```

```
/*1A02 */
        #define OD_1A02_TPDOMappingParameter                        0x1A02

        #define OD_1A02_0_TPDOMappingParameter_maxSubIndex          0
        #define OD_1A02_1_TPDOMappingParameter_mappedObject1        1
        #define OD_1A02_2_TPDOMappingParameter_mappedObject2        2
        #define OD_1A02_3_TPDOMappingParameter_mappedObject3        3
        #define OD_1A02_4_TPDOMappingParameter_mappedObject4        4
        #define OD_1A02_5_TPDOMappingParameter_mappedObject5        5
        #define OD_1A02_6_TPDOMappingParameter_mappedObject6        6
        #define OD_1A02_7_TPDOMappingParameter_mappedObject7        7
        #define OD_1A02_8_TPDOMappingParameter_mappedObject8        8

/*1A03 */
        #define OD_1A03_TPDOMappingParameter                        0x1A03

        #define OD_1A03_0_TPDOMappingParameter_maxSubIndex          0
        #define OD_1A03_1_TPDOMappingParameter_mappedObject1        1
        #define OD_1A03_2_TPDOMappingParameter_mappedObject2        2
        #define OD_1A03_3_TPDOMappingParameter_mappedObject3        3
        #define OD_1A03_4_TPDOMappingParameter_mappedObject4        4
        #define OD_1A03_5_TPDOMappingParameter_mappedObject5        5
        #define OD_1A03_6_TPDOMappingParameter_mappedObject6        6
        #define OD_1A03_7_TPDOMappingParameter_mappedObject7        7
        #define OD_1A03_8_TPDOMappingParameter_mappedObject8        8

/*1A04 */
        #define OD_1A04_TPDOMappingParameter                        0x1A04

        #define OD_1A04_0_TPDOMappingParameter_maxSubIndex          0
        #define OD_1A04_1_TPDOMappingParameter_mappedObject1        1
        #define OD_1A04_2_TPDOMappingParameter_mappedObject2        2
        #define OD_1A04_3_TPDOMappingParameter_mappedObject3        3
        #define OD_1A04_4_TPDOMappingParameter_mappedObject4        4
        #define OD_1A04_5_TPDOMappingParameter_mappedObject5        5
        #define OD_1A04_6_TPDOMappingParameter_mappedObject6        6
        #define OD_1A04_7_TPDOMappingParameter_mappedObject7        7
        #define OD_1A04_8_TPDOMappingParameter_mappedObject8        8

/*1A05 */
        #define OD_1A05_TPDOMappingParameter                        0x1A05

        #define OD_1A05_0_TPDOMappingParameter_maxSubIndex          0
        #define OD_1A05_1_TPDOMappingParameter_mappedObject1        1
        #define OD_1A05_2_TPDOMappingParameter_mappedObject2        2
        #define OD_1A05_3_TPDOMappingParameter_mappedObject3        3
        #define OD_1A05_4_TPDOMappingParameter_mappedObject4        4
        #define OD_1A05_5_TPDOMappingParameter_mappedObject5        5
        #define OD_1A05_6_TPDOMappingParameter_mappedObject6        6
        #define OD_1A05_7_TPDOMappingParameter_mappedObject7        7
        #define OD_1A05_8_TPDOMappingParameter_mappedObject8        8

/*1A06 */
        #define OD_1A06_TPDOMappingParameter                        0x1A06

        #define OD_1A06_0_TPDOMappingParameter_maxSubIndex          0
        #define OD_1A06_1_TPDOMappingParameter_mappedObject1        1
        #define OD_1A06_2_TPDOMappingParameter_mappedObject2        2
        #define OD_1A06_3_TPDOMappingParameter_mappedObject3        3
        #define OD_1A06_4_TPDOMappingParameter_mappedObject4        4
        #define OD_1A06_5_TPDOMappingParameter_mappedObject5        5
        #define OD_1A06_6_TPDOMappingParameter_mappedObject6        6
        #define OD_1A06_7_TPDOMappingParameter_mappedObject7        7
        #define OD_1A06_8_TPDOMappingParameter_mappedObject8        8
```

```
/*1A07 */
        #define OD_1A07_TPDOMappingParameter                        0x1A07

        #define OD_1A07_0_TPDOMappingParameter_maxSubIndex          0
        #define OD_1A07_1_TPDOMappingParameter_mappedObject1        1
        #define OD_1A07_2_TPDOMappingParameter_mappedObject2        2
        #define OD_1A07_3_TPDOMappingParameter_mappedObject3        3
        #define OD_1A07_4_TPDOMappingParameter_mappedObject4        4
        #define OD_1A07_5_TPDOMappingParameter_mappedObject5        5
        #define OD_1A07_6_TPDOMappingParameter_mappedObject6        6
        #define OD_1A07_7_TPDOMappingParameter_mappedObject7        7
        #define OD_1A07_8_TPDOMappingParameter_mappedObject8        8

/*1A08 */
        #define OD_1A08_TPDOMappingParameter                        0x1A08

        #define OD_1A08_0_TPDOMappingParameter_maxSubIndex          0
        #define OD_1A08_1_TPDOMappingParameter_mappedObject1        1
        #define OD_1A08_2_TPDOMappingParameter_mappedObject2        2
        #define OD_1A08_3_TPDOMappingParameter_mappedObject3        3
        #define OD_1A08_4_TPDOMappingParameter_mappedObject4        4
        #define OD_1A08_5_TPDOMappingParameter_mappedObject5        5
        #define OD_1A08_6_TPDOMappingParameter_mappedObject6        6
        #define OD_1A08_7_TPDOMappingParameter_mappedObject7        7
        #define OD_1A08_8_TPDOMappingParameter_mappedObject8        8

/*1A09 */
        #define OD_1A09_TPDOMappingParameter                        0x1A09

        #define OD_1A09_0_TPDOMappingParameter_maxSubIndex          0
        #define OD_1A09_1_TPDOMappingParameter_mappedObject1        1
        #define OD_1A09_2_TPDOMappingParameter_mappedObject2        2
        #define OD_1A09_3_TPDOMappingParameter_mappedObject3        3
        #define OD_1A09_4_TPDOMappingParameter_mappedObject4        4
        #define OD_1A09_5_TPDOMappingParameter_mappedObject5        5
        #define OD_1A09_6_TPDOMappingParameter_mappedObject6        6
        #define OD_1A09_7_TPDOMappingParameter_mappedObject7        7
        #define OD_1A09_8_TPDOMappingParameter_mappedObject8        8

/*1F80 */
        #define OD_1F80_NMTStartup                                  0x1F80

/*2100 */
        #define OD_2100_errorStatusBits                             0x2100

/*2101 */
        #define OD_2101_CANNodeID                                   0x2101

/*2102 */
        #define OD_2102_CANBitRate                                  0x2102

/*2103 */
        #define OD_2103_SYNCCounter                                 0x2103

/*2104 */
        #define OD_2104_SYNCTime                                    0x2104

/*2106 */
        #define OD_2106_powerOnCounter                              0x2106

/*2107 */
        #define OD_2107_performance                                 0x2107
```

```c
        #define OD_2107_0_performance_maxSubIndex                         0
        #define OD_2107_1_performance_cyclesPerSecond                     1
        #define OD_2107_2_performance_timerCycleTime                      2
        #define OD_2107_3_performance_timerCycleMaxTime                   3
        #define OD_2107_4_performance_mainCycleTime                       4
        #define OD_2107_5_performance_mainCycleMaxTime                    5

/*2108 */
        #define OD_2108_temperature                                       0x2108

        #define OD_2108_0_temperature_maxSubIndex                         0
        #define OD_2108_1_temperature_mainPCB                             1

/*2109 */
        #define OD_2109_voltage                                           0x2109

        #define OD_2109_0_voltage_maxSubIndex                             0
        #define OD_2109_1_voltage_mainPCBSupply                           1

/*2110 */
        #define OD_2110_variableInt32                                     0x2110

        #define OD_2110_0_variableInt32_maxSubIndex                       0
        #define OD_2110_1_variableInt32_int32                             1
        #define OD_2110_2_variableInt32_int32                             2
        #define OD_2110_3_variableInt32_int32                             3
        #define OD_2110_4_variableInt32_int32                             4
        #define OD_2110_5_variableInt32_int32                             5
        #define OD_2110_6_variableInt32_int32                             6
        #define OD_2110_7_variableInt32_int32                             7
        #define OD_2110_8_variableInt32_int32                             8
        #define OD_2110_9_variableInt32_int32                             9
        #define OD_2110_10_variableInt32_int32                            10
        #define OD_2110_11_variableInt32_int32                            11
        #define OD_2110_12_variableInt32_int32                            12
        #define OD_2110_13_variableInt32_int32                            13
        #define OD_2110_14_variableInt32_int32                            14
        #define OD_2110_15_variableInt32_int32                            15
        #define OD_2110_16_variableInt32_int32                            16

/*2111 */
        #define OD_2111_variableROM_Int32                                 0x2111

        #define OD_2111_0_variableROM_Int32_maxSubIndex                   0
        #define OD_2111_1_variableROM_Int32_int32                         1
        #define OD_2111_2_variableROM_Int32_int32                         2
        #define OD_2111_3_variableROM_Int32_int32                         3
        #define OD_2111_4_variableROM_Int32_int32                         4
        #define OD_2111_5_variableROM_Int32_int32                         5
        #define OD_2111_6_variableROM_Int32_int32                         6
        #define OD_2111_7_variableROM_Int32_int32                         7
        #define OD_2111_8_variableROM_Int32_int32                         8
        #define OD_2111_9_variableROM_Int32_int32                         9
        #define OD_2111_10_variableROM_Int32_int32                        10
        #define OD_2111_11_variableROM_Int32_int32                        11
        #define OD_2111_12_variableROM_Int32_int32                        12
        #define OD_2111_13_variableROM_Int32_int32                        13
        #define OD_2111_14_variableROM_Int32_int32                        14
        #define OD_2111_15_variableROM_Int32_int32                        15
        #define OD_2111_16_variableROM_Int32_int32                        16

/*2112 */
        #define OD_2112_variableNV_Int32                                  0x2112
```

```
        #define OD_2112_0_variableNV_Int32_maxSubIndex              0
        #define OD_2112_1_variableNV_Int32_int32                    1
        #define OD_2112_2_variableNV_Int32_int32                    2
        #define OD_2112_3_variableNV_Int32_int32                    3
        #define OD_2112_4_variableNV_Int32_int32                    4
        #define OD_2112_5_variableNV_Int32_int32                    5
        #define OD_2112_6_variableNV_Int32_int32                    6
        #define OD_2112_7_variableNV_Int32_int32                    7
        #define OD_2112_8_variableNV_Int32_int32                    8
        #define OD_2112_9_variableNV_Int32_int32                    9
        #define OD_2112_10_variableNV_Int32_int32                   10
        #define OD_2112_11_variableNV_Int32_int32                   11
        #define OD_2112_12_variableNV_Int32_int32                   12
        #define OD_2112_13_variableNV_Int32_int32                   13
        #define OD_2112_14_variableNV_Int32_int32                   14
        #define OD_2112_15_variableNV_Int32_int32                   15
        #define OD_2112_16_variableNV_Int32_int32                   16

/*2120 */
        #define OD_2120_testVar                                     0x2120

        #define OD_2120_0_testVar_maxSubIndex                       0
        #define OD_2120_1_testVar_I64                               1
        #define OD_2120_2_testVar_U64                               2
        #define OD_2120_3_testVar_R32                               3
        #define OD_2120_4_testVar_R64                               4
        #define OD_2120_5_testVar_domain                            5

/*2130 */
        #define OD_2130_time                                        0x2130

        #define OD_2130_0_time_maxSubIndex                          0
        #define OD_2130_1_time_string                               1
        #define OD_2130_2_time_epochTimeBaseMs                      2
        #define OD_2130_3_time_epochTimeOffsetMs                    3

/*2301 */
        #define OD_2301_traceConfig                                 0x2301

        #define OD_2301_0_traceConfig_maxSubIndex                   0
        #define OD_2301_1_traceConfig_size                          1
        #define OD_2301_2_traceConfig_axisNo                        2
        #define OD_2301_3_traceConfig_name                          3
        #define OD_2301_4_traceConfig_color                         4
        #define OD_2301_5_traceConfig_map                           5
        #define OD_2301_6_traceConfig_format                        6
        #define OD_2301_7_traceConfig_trigger                       7
        #define OD_2301_8_traceConfig_threshold                     8

/*2302 */
        #define OD_2302_traceConfig                                 0x2302

        #define OD_2302_0_traceConfig_maxSubIndex                   0
        #define OD_2302_1_traceConfig_size                          1
        #define OD_2302_2_traceConfig_axisNo                        2
        #define OD_2302_3_traceConfig_name                          3
        #define OD_2302_4_traceConfig_color                         4
        #define OD_2302_5_traceConfig_map                           5
        #define OD_2302_6_traceConfig_format                        6
        #define OD_2302_7_traceConfig_trigger                       7
        #define OD_2302_8_traceConfig_threshold                     8

/*2400 */
        #define OD_2400_traceEnable                                 0x2400
```

```
/*2401 */
        #define OD_2401_trace                                          0x2401

        #define OD_2401_0_trace_maxSubIndex                            0
        #define OD_2401_1_trace_size                                   1
        #define OD_2401_2_trace_value                                  2
        #define OD_2401_3_trace_min                                    3
        #define OD_2401_4_trace_max                                    4
        #define OD_2401_5_trace_plot                                   5
        #define OD_2401_6_trace_triggerTime                            6

/*2402 */
        #define OD_2402_trace                                          0x2402

        #define OD_2402_0_trace_maxSubIndex                            0
        #define OD_2402_1_trace_size                                   1
        #define OD_2402_2_trace_value                                  2
        #define OD_2402_3_trace_min                                    3
        #define OD_2402_4_trace_max                                    4
        #define OD_2402_5_trace_plot                                   5
        #define OD_2402_6_trace_triggerTime                            6

/*6010 */
        #define OD_6010_IGUS_D1Controlword1                            0x6010

/*6011 */
        #define OD_6011_IGUS_D1Statusword1                             0x6011

/*6012 */
        #define OD_6012_IGUS_D1PositionActualValue1                    0x6012

/*6013 */
        #define OD_6013_IGUS_D1VelocityActualValue1                    0x6013

/*6014 */
        #define OD_6014_IGUS_D1TargetPosition1                         0x6014

/*6015 */
        #define OD_6015_IGUS_D1TargetVelocity1                         0x6015

/*6020 */
        #define OD_6020_IGUS_D1Controlword2                            0x6020

/*6021 */
        #define OD_6021_IGUS_D1Statusword2                             0x6021

/*6022 */
        #define OD_6022_IGUS_D1PositionActualValue2                    0x6022

/*6023 */
        #define OD_6023_IGUS_D1VelocityActualValue2                    0x6023

/*6024 */
        #define OD_6024_IGUS_D1TargetPosition2                         0x6024

/*6025 */
        #define OD_6025_IGUS_D1TargetVelocity2                         0x6025

/*6030 */
        #define OD_6030_IGUS_D1Controlword3                            0x6030

/*6031 */
        #define OD_6031_IGUS_D1Statusword3                             0x6031
```

```
/*6032 */
        #define OD_6032_IGUS_D1PositionActualValue3                 0x6032

/*6033 */
        #define OD_6033_IGUS_D1VelocityActualValue3                 0x6033

/*6034 */
        #define OD_6034_IGUS_D1TargetPosition3                      0x6034

/*6035 */
        #define OD_6035_IGUS_D1TargetVelocity3                      0x6035

/*6040 */
        #define OD_6040_IGUS_D1Controlword4                         0x6040

/*6041 */
        #define OD_6041_IGUS_D1Statusword4                          0x6041

/*6042 */
        #define OD_6042_IGUS_D1PositionActualValue4                 0x6042

/*6043 */
        #define OD_6043_IGUS_D1VelocityActualValue4                 0x6043

/*6044 */
        #define OD_6044_IGUS_D1TargetPosition4                      0x6044

/*6045 */
        #define OD_6045_IGUS_D1TargetVelocity4                      0x6045

/*6050 */
        #define OD_6050_IGUS_D1Controlword5                         0x6050

/*6051 */
        #define OD_6051_IGUS_D1Statusword5                          0x6051

/*6052 */
        #define OD_6052_IGUS_D1PositionActualValue5                 0x6052

/*6053 */
        #define OD_6053_IGUS_D1VelocityActualValue5                 0x6053

/*6054 */
        #define OD_6054_IGUS_D1TargetPosition5                      0x6054

/*6055 */
        #define OD_6055_IGUS_D1TargetVelocity5                      0x6055

/*6060 */
        #define OD_6060_IGUS_D1Controlword6                         0x6060

/*6061 */
        #define OD_6061_IGUS_D1Statusword6                          0x6061

/*6062 */
        #define OD_6062_IGUS_D1PositionActualValue6                 0x6062

/*6063 */
        #define OD_6063_IGUS_D1VelocityActualValue6                 0x6063

/*6064 */
        #define OD_6064_IGUS_D1TargetPosition6                      0x6064
```

```
/*6065 */
        #define OD_6065_IGUS_D1TargetVelocity6                          0x6065

/*60A0 */
        #define OD_60A0_motorControlword1                               0x60A0

/*60A1 */
        #define OD_60A1_motorStatusword1                                0x60A1

/*60A2 */
        #define OD_60A2_motorTargetVelocity1                            0x60A2

/*60A3 */
        #define OD_60A3_motorActualVelocity1                            0x60A3

/*60B0 */
        #define OD_60B0_motorControlword2                               0x60B0

/*60B1 */
        #define OD_60B1_motorStatusword2                                0x60B1

/*60B2 */
        #define OD_60B2_motorTargetVelocity2                            0x60B2

/*60B3 */
        #define OD_60B3_motorActualVelocity2                            0x60B3

/*60C0 */
        #define OD_60C0_motorControlword3                               0x60C0

/*60C1 */
        #define OD_60C1_motorStatusword3                                0x60C1

/*60C2 */
        #define OD_60C2_motorTargetVelocity3                            0x60C2

/*60C3 */
        #define OD_60C3_motorActualVelocity3                            0x60C3

/*60D0 */
        #define OD_60D0_motorControlword4                               0x60D0

/*60D1 */
        #define OD_60D1_motorStatusword4                                0x60D1

/*60D2 */
        #define OD_60D2_motorTargetVelocity4                            0x60D2

/*60D3 */
        #define OD_60D3_motorActualVelocity4                            0x60D3

/*******************************************************************************
   STRUCTURES FOR VARIABLES IN DIFFERENT MEMORY LOCATIONS
*******************************************************************************/
#define  CO_OD_FIRST_LAST_WORD     0x55 //Any value from 0x01 to 0xFE. If changed, EEPROM
will be reinitialized.

/***** Structure for ROM variables ********************************************/
struct sCO_OD_ROM{
               UNSIGNED32     FirstWord;


               UNSIGNED32     LastWord;
};
```

```
/***** Structure for RAM variables ********************************************/
struct sCO_OD_RAM{
               UNSIGNED32     FirstWord;

/*0005      */ UNSIGNED8      compatabilityEntry;
/*1000      */ UNSIGNED32     deviceType;
/*1001      */ UNSIGNED8      errorRegister;
/*1002      */ UNSIGNED32     manufacturerStatusRegister;
/*1003      */ UNSIGNED32      preDefinedErrorField[8];
/*1006      */ UNSIGNED32     communicationCyclePeriod;
/*1007      */ UNSIGNED32     synchronousWindowLength;
/*1008      */ VISIBLE_STRING manufacturerDeviceName[11];
/*1009      */ VISIBLE_STRING manufacturerHardwareVersion[4];
/*100A      */ VISIBLE_STRING manufacturerSoftwareVersion[4];
/*1010      */ UNSIGNED32      storeParameters[1];
/*1011      */ UNSIGNED32      restoreDefaultParameters[1];
/*1014      */ UNSIGNED32     COB_ID_EMCY;
/*1015      */ UNSIGNED16     inhibitTimeEMCY;
/*1016      */ UNSIGNED32      consumerHeartbeatTime[4];
/*1017      */ UNSIGNED16     producerHeartbeatTime;
/*1018      */ OD_identity_t   identity;
/*1019      */ UNSIGNED8      synchronousCounterOverflowValue;
/*1029      */ UNSIGNED8       errorBehavior[6];
/*1200      */ OD_SDOServerParameter_t SDOServerParameter[1];
/*1280      */ OD_SDOClientParameter_t SDOClientParameter[1];
/*1400      */ OD_RPDOCommunicationParameter_t RPDOCommunicationParameter[10];
/*1600      */ OD_RPDOMappingParameter_t RPDOMappingParameter[10];
/*1800      */ OD_TPDOCommunicationParameter_t TPDOCommunicationParameter[10];
/*1A00      */ OD_TPDOMappingParameter_t TPDOMappingParameter[10];
/*1F80      */ UNSIGNED32     NMTStartup;
/*2100      */ OCTET_STRING   errorStatusBits[10];
/*2101      */ UNSIGNED8      CANNodeID;
/*2102      */ UNSIGNED16     CANBitRate;
/*2103      */ UNSIGNED16     SYNCCounter;
/*2104      */ UNSIGNED16     SYNCTime;
/*2106      */ UNSIGNED32     powerOnCounter;
/*2107      */ UNSIGNED16      performance[5];
/*2108      */ INTEGER16       temperature[1];
/*2109      */ INTEGER16       voltage[1];
/*2110      */ INTEGER32       variableInt32[16];
/*2111      */ INTEGER32       variableROM_Int32[16];
/*2112      */ INTEGER32       variableNV_Int32[16];
/*2120      */ OD_testVar_t    testVar;
/*2130      */ OD_time_t       time;
/*2301      */ OD_traceConfig_t traceConfig[2];
/*2400      */ UNSIGNED8      traceEnable;
/*2401      */ OD_trace_t      trace[2];
/*6010      */ UNSIGNED16     IGUS_D1Controlword1;
/*6011      */ UNSIGNED16     IGUS_D1Statusword1;
/*6012      */ INTEGER32      IGUS_D1PositionActualValue1;
/*6013      */ INTEGER32      IGUS_D1VelocityActualValue1;
/*6014      */ INTEGER32      IGUS_D1TargetPosition1;
/*6015      */ INTEGER32      IGUS_D1TargetVelocity1;
/*6020      */ UNSIGNED16     IGUS_D1Controlword2;
/*6021      */ UNSIGNED16     IGUS_D1Statusword2;
/*6022      */ INTEGER32      IGUS_D1PositionActualValue2;
/*6023      */ INTEGER32      IGUS_D1VelocityActualValue2;
/*6024      */ INTEGER32      IGUS_D1TargetPosition2;
/*6025      */ INTEGER32      IGUS_D1TargetVelocity2;
/*6030      */ UNSIGNED16     IGUS_D1Controlword3;
/*6031      */ UNSIGNED16     IGUS_D1Statusword3;
/*6032      */ INTEGER32      IGUS_D1PositionActualValue3;
/*6033      */ INTEGER32      IGUS_D1VelocityActualValue3;
```

```
/*6034      */ INTEGER32      IGUS_D1TargetPosition3;
/*6035      */ INTEGER32      IGUS_D1TargetVelocity3;
/*6040      */ UNSIGNED16     IGUS_D1Controlword4;
/*6041      */ UNSIGNED16     IGUS_D1Statusword4;
/*6042      */ INTEGER32      IGUS_D1PositionActualValue4;
/*6043      */ INTEGER32      IGUS_D1VelocityActualValue4;
/*6044      */ INTEGER32      IGUS_D1TargetPosition4;
/*6045      */ INTEGER32      IGUS_D1TargetVelocity4;
/*6050      */ UNSIGNED16     IGUS_D1Controlword5;
/*6051      */ UNSIGNED16     IGUS_D1Statusword5;
/*6052      */ INTEGER32      IGUS_D1PositionActualValue5;
/*6053      */ INTEGER32      IGUS_D1VelocityActualValue5;
/*6054      */ INTEGER32      IGUS_D1TargetPosition5;
/*6055      */ INTEGER32      IGUS_D1TargetVelocity5;
/*6060      */ UNSIGNED16     IGUS_D1Controlword6;
/*6061      */ UNSIGNED16     IGUS_D1Statusword6;
/*6062      */ INTEGER32      IGUS_D1PositionActualValue6;
/*6063      */ INTEGER32      IGUS_D1VelocityActualValue6;
/*6064      */ INTEGER32      IGUS_D1TargetPosition6;
/*6065      */ INTEGER32      IGUS_D1TargetVelocity6;
/*60A0      */ UNSIGNED16     motorControlword1;
/*60A1      */ UNSIGNED16     motorStatusword1;
/*60A2      */ INTEGER16      motorTargetVelocity1;
/*60A3      */ INTEGER16      motorActualVelocity1;
/*60B0      */ UNSIGNED16     motorControlword2;
/*60B1      */ UNSIGNED16     motorStatusword2;
/*60B2      */ INTEGER16      motorTargetVelocity2;
/*60B3      */ INTEGER16      motorActualVelocity2;
/*60C0      */ UNSIGNED16     motorControlword3;
/*60C1      */ UNSIGNED16     motorStatusword3;
/*60C2      */ INTEGER16      motorTargetVelocity3;
/*60C3      */ INTEGER16      motorActualVelocity3;
/*60D0      */ UNSIGNED16     motorControlword4;
/*60D1      */ UNSIGNED16     motorStatusword4;
/*60D2      */ INTEGER16      motorTargetVelocity4;
/*60D3      */ INTEGER16      motorActualVelocity4;

               UNSIGNED32     LastWord;
};

/***** Structure for EEPROM variables ********************************************/
struct sCO_OD_EEPROM{
               UNSIGNED32     FirstWord;


               UNSIGNED32     LastWord;
};

/***** Declaration of Object Dictionary variables *****************************/
extern struct sCO_OD_ROM CO_OD_ROM;

extern struct sCO_OD_RAM CO_OD_RAM;

extern struct sCO_OD_EEPROM CO_OD_EEPROM;

/*******************************************************************************
   ALIASES FOR OBJECT DICTIONARY VARIABLES
*******************************************************************************/
/*0005, Data Type: UNSIGNED8 */
        #define OD_compatabilityEntry
CO_OD_RAM.compatabilityEntry

/*1000, Data Type: UNSIGNED32 */
        #define OD_deviceType                                       CO_OD_RAM.deviceType
```

```
/*1001, Data Type: UNSIGNED8 */
        #define OD_errorRegister
CO_OD_RAM.errorRegister

/*1002, Data Type: UNSIGNED32 */
        #define OD_manufacturerStatusRegister
CO_OD_RAM.manufacturerStatusRegister

/*1003, Data Type: UNSIGNED32, Array[8] */
        #define OD_preDefinedErrorField
CO_OD_RAM.preDefinedErrorField
        #define ODL_preDefinedErrorField_arrayLength                8
        #define ODA_preDefinedErrorField_standardErrorField         0

/*1006, Data Type: UNSIGNED32 */
        #define OD_communicationCyclePeriod
CO_OD_RAM.communicationCyclePeriod

/*1007, Data Type: UNSIGNED32 */
        #define OD_synchronousWindowLength
CO_OD_RAM.synchronousWindowLength

/*1008, Data Type: VISIBLE_STRING */
        #define OD_manufacturerDeviceName
CO_OD_RAM.manufacturerDeviceName
        #define ODL_manufacturerDeviceName_stringLength             11

/*1009, Data Type: VISIBLE_STRING */
        #define OD_manufacturerHardwareVersion
CO_OD_RAM.manufacturerHardwareVersion
        #define ODL_manufacturerHardwareVersion_stringLength        4

/*100A, Data Type: VISIBLE_STRING */
        #define OD_manufacturerSoftwareVersion
CO_OD_RAM.manufacturerSoftwareVersion
        #define ODL_manufacturerSoftwareVersion_stringLength        4

/*1010, Data Type: UNSIGNED32, Array[1] */
        #define OD_storeParameters
CO_OD_RAM.storeParameters
        #define ODL_storeParameters_arrayLength                     1
        #define ODA_storeParameters_saveAllParameters               0

/*1011, Data Type: UNSIGNED32, Array[1] */
        #define OD_restoreDefaultParameters
CO_OD_RAM.restoreDefaultParameters
        #define ODL_restoreDefaultParameters_arrayLength            1
        #define ODA_restoreDefaultParameters_restoreAllDefaultParameters 0

/*1014, Data Type: UNSIGNED32 */
        #define OD_COB_ID_EMCY                                      CO_OD_RAM.COB_ID_EMCY

/*1015, Data Type: UNSIGNED16 */
        #define OD_inhibitTimeEMCY
CO_OD_RAM.inhibitTimeEMCY

/*1016, Data Type: UNSIGNED32, Array[4] */
        #define OD_consumerHeartbeatTime
CO_OD_RAM.consumerHeartbeatTime
        #define ODL_consumerHeartbeatTime_arrayLength               4
        #define ODA_consumerHeartbeatTime_consumerHeartbeatTime     0

/*1017, Data Type: UNSIGNED16 */
```

```
        #define OD_producerHeartbeatTime
CO_OD_RAM.producerHeartbeatTime

/*1018, Data Type: identity_t */
        #define OD_identity                                         CO_OD_RAM.identity

/*1019, Data Type: UNSIGNED8 */
        #define OD_synchronousCounterOverflowValue
CO_OD_RAM.synchronousCounterOverflowValue

/*1029, Data Type: UNSIGNED8, Array[6] */
        #define OD_errorBehavior
CO_OD_RAM.errorBehavior
        #define ODL_errorBehavior_arrayLength                       6
        #define ODA_errorBehavior_communication                     0
        #define ODA_errorBehavior_communicationOther                1
        #define ODA_errorBehavior_communicationPassive              2
        #define ODA_errorBehavior_generic                           3
        #define ODA_errorBehavior_deviceProfile                     4
        #define ODA_errorBehavior_manufacturerSpecific              5

/*1200, Data Type: SDOServerParameter_t */
        #define OD_SDOServerParameter
CO_OD_RAM.SDOServerParameter

/*1280, Data Type: SDOClientParameter_t */
        #define OD_SDOClientParameter
CO_OD_RAM.SDOClientParameter

/*1400, Data Type: RPDOCommunicationParameter_t */
        #define OD_RPDOCommunicationParameter
CO_OD_RAM.RPDOCommunicationParameter

/*1600, Data Type: RPDOMappingParameter_t */
        #define OD_RPDOMappingParameter
CO_OD_RAM.RPDOMappingParameter

/*1800, Data Type: TPDOCommunicationParameter_t */
        #define OD_TPDOCommunicationParameter
CO_OD_RAM.TPDOCommunicationParameter

/*1A00, Data Type: TPDOMappingParameter_t */
        #define OD_TPDOMappingParameter
CO_OD_RAM.TPDOMappingParameter

/*1F80, Data Type: UNSIGNED32 */
        #define OD_NMTStartup                                       CO_OD_RAM.NMTStartup

/*2100, Data Type: OCTET_STRING */
        #define OD_errorStatusBits
CO_OD_RAM.errorStatusBits
        #define ODL_errorStatusBits_stringLength                    10

/*2101, Data Type: UNSIGNED8 */
        #define OD_CANNodeID                                        CO_OD_RAM.CANNodeID

/*2102, Data Type: UNSIGNED16 */
        #define OD_CANBitRate                                       CO_OD_RAM.CANBitRate

/*2103, Data Type: UNSIGNED16 */
        #define OD_SYNCCounter                                      CO_OD_RAM.SYNCCounter

/*2104, Data Type: UNSIGNED16 */
        #define OD_SYNCTime                                         CO_OD_RAM.SYNCTime
```

```
/*2106, Data Type: UNSIGNED32 */
        #define OD_powerOnCounter
CO_OD_RAM.powerOnCounter

/*2107, Data Type: UNSIGNED16, Array[5] */
        #define OD_performance                                  CO_OD_RAM.performance
        #define ODL_performance_arrayLength                     5
        #define ODA_performance_cyclesPerSecond                 0
        #define ODA_performance_timerCycleTime                  1
        #define ODA_performance_timerCycleMaxTime               2
        #define ODA_performance_mainCycleTime                   3
        #define ODA_performance_mainCycleMaxTime                4

/*2108, Data Type: INTEGER16, Array[1] */
        #define OD_temperature                                  CO_OD_RAM.temperature
        #define ODL_temperature_arrayLength                     1
        #define ODA_temperature_mainPCB                         0

/*2109, Data Type: INTEGER16, Array[1] */
        #define OD_voltage                                      CO_OD_RAM.voltage
        #define ODL_voltage_arrayLength                         1
        #define ODA_voltage_mainPCBSupply                       0

/*2110, Data Type: INTEGER32, Array[16] */
        #define OD_variableInt32
CO_OD_RAM.variableInt32
        #define ODL_variableInt32_arrayLength                   16
        #define ODA_variableInt32_int32                         0

/*2111, Data Type: INTEGER32, Array[16] */
        #define OD_variableROM_Int32
CO_OD_RAM.variableROM_Int32
        #define ODL_variableROM_Int32_arrayLength               16
        #define ODA_variableROM_Int32_int32                     0

/*2112, Data Type: INTEGER32, Array[16] */
        #define OD_variableNV_Int32
CO_OD_RAM.variableNV_Int32
        #define ODL_variableNV_Int32_arrayLength                16
        #define ODA_variableNV_Int32_int32                      0

/*2120, Data Type: testVar_t */
        #define OD_testVar                                      CO_OD_RAM.testVar

/*2130, Data Type: time_t */
        #define OD_time                                         CO_OD_RAM.time

/*2301, Data Type: traceConfig_t */
        #define OD_traceConfig                                  CO_OD_RAM.traceConfig

/*2400, Data Type: UNSIGNED8 */
        #define OD_traceEnable                                  CO_OD_RAM.traceEnable

/*2401, Data Type: trace_t */
        #define OD_trace                                        CO_OD_RAM.trace

/*6010, Data Type: UNSIGNED16 */
        #define OD_IGUS_D1Controlword1
CO_OD_RAM.IGUS_D1Controlword1

/*6011, Data Type: UNSIGNED16 */
        #define OD_IGUS_D1Statusword1
CO_OD_RAM.IGUS_D1Statusword1
```

```
/*6012, Data Type: INTEGER32 */
        #define OD_IGUS_D1PositionActualValue1
CO_OD_RAM.IGUS_D1PositionActualValue1

/*6013, Data Type: INTEGER32 */
        #define OD_IGUS_D1VelocityActualValue1
CO_OD_RAM.IGUS_D1VelocityActualValue1

/*6014, Data Type: INTEGER32 */
        #define OD_IGUS_D1TargetPosition1
CO_OD_RAM.IGUS_D1TargetPosition1

/*6015, Data Type: INTEGER32 */
        #define OD_IGUS_D1TargetVelocity1
CO_OD_RAM.IGUS_D1TargetVelocity1

/*6020, Data Type: UNSIGNED16 */
        #define OD_IGUS_D1Controlword2
CO_OD_RAM.IGUS_D1Controlword2

/*6021, Data Type: UNSIGNED16 */
        #define OD_IGUS_D1Statusword2
CO_OD_RAM.IGUS_D1Statusword2

/*6022, Data Type: INTEGER32 */
        #define OD_IGUS_D1PositionActualValue2
CO_OD_RAM.IGUS_D1PositionActualValue2

/*6023, Data Type: INTEGER32 */
        #define OD_IGUS_D1VelocityActualValue2
CO_OD_RAM.IGUS_D1VelocityActualValue2

/*6024, Data Type: INTEGER32 */
        #define OD_IGUS_D1TargetPosition2
CO_OD_RAM.IGUS_D1TargetPosition2

/*6025, Data Type: INTEGER32 */
        #define OD_IGUS_D1TargetVelocity2
CO_OD_RAM.IGUS_D1TargetVelocity2

/*6030, Data Type: UNSIGNED16 */
        #define OD_IGUS_D1Controlword3
CO_OD_RAM.IGUS_D1Controlword3

/*6031, Data Type: UNSIGNED16 */
        #define OD_IGUS_D1Statusword3
CO_OD_RAM.IGUS_D1Statusword3

/*6032, Data Type: INTEGER32 */
        #define OD_IGUS_D1PositionActualValue3
CO_OD_RAM.IGUS_D1PositionActualValue3

/*6033, Data Type: INTEGER32 */
        #define OD_IGUS_D1VelocityActualValue3
CO_OD_RAM.IGUS_D1VelocityActualValue3

/*6034, Data Type: INTEGER32 */
        #define OD_IGUS_D1TargetPosition3
CO_OD_RAM.IGUS_D1TargetPosition3

/*6035, Data Type: INTEGER32 */
        #define OD_IGUS_D1TargetVelocity3
CO_OD_RAM.IGUS_D1TargetVelocity3
```

```
/*6040, Data Type: UNSIGNED16 */
        #define OD_IGUS_D1Controlword4
CO_OD_RAM.IGUS_D1Controlword4

/*6041, Data Type: UNSIGNED16 */
        #define OD_IGUS_D1Statusword4
CO_OD_RAM.IGUS_D1Statusword4

/*6042, Data Type: INTEGER32 */
        #define OD_IGUS_D1PositionActualValue4
CO_OD_RAM.IGUS_D1PositionActualValue4

/*6043, Data Type: INTEGER32 */
        #define OD_IGUS_D1VelocityActualValue4
CO_OD_RAM.IGUS_D1VelocityActualValue4

/*6044, Data Type: INTEGER32 */
        #define OD_IGUS_D1TargetPosition4
CO_OD_RAM.IGUS_D1TargetPosition4

/*6045, Data Type: INTEGER32 */
        #define OD_IGUS_D1TargetVelocity4
CO_OD_RAM.IGUS_D1TargetVelocity4

/*6050, Data Type: UNSIGNED16 */
        #define OD_IGUS_D1Controlword5
CO_OD_RAM.IGUS_D1Controlword5

/*6051, Data Type: UNSIGNED16 */
        #define OD_IGUS_D1Statusword5
CO_OD_RAM.IGUS_D1Statusword5

/*6052, Data Type: INTEGER32 */
        #define OD_IGUS_D1PositionActualValue5
CO_OD_RAM.IGUS_D1PositionActualValue5

/*6053, Data Type: INTEGER32 */
        #define OD_IGUS_D1VelocityActualValue5
CO_OD_RAM.IGUS_D1VelocityActualValue5

/*6054, Data Type: INTEGER32 */
        #define OD_IGUS_D1TargetPosition5
CO_OD_RAM.IGUS_D1TargetPosition5

/*6055, Data Type: INTEGER32 */
        #define OD_IGUS_D1TargetVelocity5
CO_OD_RAM.IGUS_D1TargetVelocity5

/*6060, Data Type: UNSIGNED16 */
        #define OD_IGUS_D1Controlword6
CO_OD_RAM.IGUS_D1Controlword6

/*6061, Data Type: UNSIGNED16 */
        #define OD_IGUS_D1Statusword6
CO_OD_RAM.IGUS_D1Statusword6

/*6062, Data Type: INTEGER32 */
        #define OD_IGUS_D1PositionActualValue6
CO_OD_RAM.IGUS_D1PositionActualValue6

/*6063, Data Type: INTEGER32 */
        #define OD_IGUS_D1VelocityActualValue6
CO_OD_RAM.IGUS_D1VelocityActualValue6
```

```
/*6064, Data Type: INTEGER32 */
        #define OD_IGUS_D1TargetPosition6
CO_OD_RAM.IGUS_D1TargetPosition6

/*6065, Data Type: INTEGER32 */
        #define OD_IGUS_D1TargetVelocity6
CO_OD_RAM.IGUS_D1TargetVelocity6

/*60A0, Data Type: UNSIGNED16 */
        #define OD_motorControlword1
CO_OD_RAM.motorControlword1

/*60A1, Data Type: UNSIGNED16 */
        #define OD_motorStatusword1
CO_OD_RAM.motorStatusword1

/*60A2, Data Type: INTEGER16 */
        #define OD_motorTargetVelocity1
CO_OD_RAM.motorTargetVelocity1

/*60A3, Data Type: INTEGER16 */
        #define OD_motorActualVelocity1
CO_OD_RAM.motorActualVelocity1

/*60B0, Data Type: UNSIGNED16 */
        #define OD_motorControlword2
CO_OD_RAM.motorControlword2

/*60B1, Data Type: UNSIGNED16 */
        #define OD_motorStatusword2
CO_OD_RAM.motorStatusword2

/*60B2, Data Type: INTEGER16 */
        #define OD_motorTargetVelocity2
CO_OD_RAM.motorTargetVelocity2

/*60B3, Data Type: INTEGER16 */
        #define OD_motorActualVelocity2
CO_OD_RAM.motorActualVelocity2

/*60C0, Data Type: UNSIGNED16 */
        #define OD_motorControlword3
CO_OD_RAM.motorControlword3

/*60C1, Data Type: UNSIGNED16 */
        #define OD_motorStatusword3
CO_OD_RAM.motorStatusword3

/*60C2, Data Type: INTEGER16 */
        #define OD_motorTargetVelocity3
CO_OD_RAM.motorTargetVelocity3

/*60C3, Data Type: INTEGER16 */
        #define OD_motorActualVelocity3
CO_OD_RAM.motorActualVelocity3

/*60D0, Data Type: UNSIGNED16 */
        #define OD_motorControlword4
CO_OD_RAM.motorControlword4

/*60D1, Data Type: UNSIGNED16 */
        #define OD_motorStatusword4
CO_OD_RAM.motorStatusword4
```

```
/*60D2, Data Type: INTEGER16 */
        #define OD_motorTargetVelocity4
CO_OD_RAM.motorTargetVelocity4

/*60D3, Data Type: INTEGER16 */
        #define OD_motorActualVelocity4
CO_OD_RAM.motorActualVelocity4

#endif
// clang-format on
```

Fails "communicatorApp.c"

```
/*******************************************************************************
  MPLAB Harmony Application Source File

  Company:
    Microchip Technology Inc.

  File Name:
    communicatorapp.c

  Summary:
    This file contains the source code for the MPLAB Harmony application.

  Description:
    This file contains the source code for the MPLAB Harmony application.  It
    implements the logic of the application's state machine and it may call
    API routines of other MPLAB Harmony modules in the system, such as drivers,
    system services, and middleware.  However, it does not call any of the
    system interfaces (such as the "Initialize" and "Tasks" functions) of any of
    the modules in the system or make any assumptions about when those functions
    are called.  That is the responsibility of the configuration-specific system
    files.
 *******************************************************************************/

// DOM-IGNORE-BEGIN
/*******************************************************************************
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(INCLUDING BUT NOT LIMITED TO ANY DEFENSE THEREOF), OR OTHER SIMILAR COSTS.
 *******************************************************************************/
// DOM-IGNORE-END


// *****************************************************************************
// *****************************************************************************
// Section: Included Files
// *****************************************************************************
// *****************************************************************************

#include "communicatorapp.h"
#include "UDPComm/PIC32_Harmony/udpcomm.h"

// *****************************************************************************
// *****************************************************************************
// Section: Global Data Definitions
// *****************************************************************************
```

```c
// *****************************************************************************

// *****************************************************************************
/* Application Data

  Summary:
    Holds application data

  Description:
    This structure holds the application's data.

  Remarks:
    This structure should be initialized by the APP_Initialize function.

    Application strings and buffers are be defined outside this structure.
*/

COMMUNICATORAPP_DATA commAppData;

// *****************************************************************************
// *****************************************************************************
// Section: Application Callback Functions
// *****************************************************************************
// *****************************************************************************

/* TODO:  Add any necessary callback functions.
*/

// *****************************************************************************
// *****************************************************************************
// Section: Application Local Functions
// *****************************************************************************
// *****************************************************************************


/* TODO:  Add any necessary local functions.
*/


// *****************************************************************************
// *****************************************************************************
// Section: Application Initialization and State Machine Functions
// *****************************************************************************
// *****************************************************************************

/*******************************************************************************
  Function:
    void COMMUNICATORAPP_Initialize ( void )

  Remarks:
    See prototype in communicatorapp.h.
 */

void COMMUNICATORAPP_Initialize ( void )
{
    UDPCOMM_Initialise();

    /* Place the App state machine in its initial state. */
    commAppData.state = COMMUNICATORAPP_WAIT_INIT;
    commAppData.Flags.Word = 0;

    /* TODO: Initialize your application's state machine and other
     * parameters.
     */
```

```
}


/*******************************************************************************
  Function:
    void COMMUNICATORAPP_Tasks ( void )

  Remarks:
    See prototype in communicatorapp.h.
 */

void COMMUNICATORAPP_Tasks ( void )
{
    SYS_STATUS          tcpipStat;
    int                 i, nNets, byteCnt, charCnt;
    int16_t             p1, p2, p3, p4, p5;
    uint8_t *ptr, *c;
    int8_t *s;
    TCPIP_NET_HANDLE    netH;
    const char          *netName;
    IPV4_ADDR           ipAddr;
    bool res;
    RONIN_COMM_INTERFACE_TYPE comInterfaceType;



    UDPCOMM_Tasks();
    /* Check the application's current state. */
    switch ( commAppData.state )
    {
        /* Application's initial state. */
        case COMMUNICATORAPP_WAIT_INIT:
        {
            if (UDPCOMM_GetState() == UDPCOMM_READY)
                commAppData.state  = COMMUNICATORAPP_IDLE;
                break;
        }

        case COMMUNICATORAPP_IDLE:

            if (byteCnt = UDPCOMM_GetBytes( commAppData.RemoteCommandBuff,
                                            sizeof(commAppData.RemoteCommandBuff)))
            {
                commAppData.RemoteCommandBuff[byteCnt] = '\0';
                RONIN_COMMAND_PROC_ParseString(commAppData.RemoteCommandBuff);
            }

            charCnt = sprintf(commAppData.TxBuff, "%d;", commAppData.PacketsSent);
            comInterfaceType = RONIN_COMMAND_PROC_GetStringToSend(commAppData.TxBuff +
charCnt);
            switch (comInterfaceType)
            {
                case RONIN_COMM_NO_DATA:
                    break;
                case RONIN_COMM_INTERFACE_FAST:
                    UDPCOMM_PutBytes(commAppData.TxBuff, strlen(commAppData.TxBuff));
                    commAppData.PacketsSent++;
                    break;
                case RONIN_COMM_INTERFACE_RELIABLE:
                    //Not implemented
                    break;
            }
            break;
        /* TODO: implement your application state machine.*/
```

```
        /* The default state should never be executed. */
        default:
        {
            /* TODO: Handle error in application's state machine. */
            break;
        }
    }
    if (commAppData.state > COMMUNICATORAPP_WAIT_FOR_CONNECTION)
    {
//        if (!TCPIP_UDP_IsConnected(commAppData.ClientSocketHandle))
//        {
//            SYS_CONSOLE_MESSAGE("Connection closed!\r\n");
//            commAppData.state = COMMUNICATORAPP_WAIT_FOR_IP;
//        }
    }
}


/*******************************************************************************
 End of File
 */
```

Fails "communicatorApp.h"

```
/*******************************************************************************
  MPLAB Harmony Application Header File

  Company:
    Microchip Technology Inc.

  File Name:
    communicatorapp.h

  Summary:
    This header file provides prototypes and definitions for the application.

  Description:
    This header file provides function prototypes and data type definitions for
    the application.  Some of these are required by the system (such as the
    "APP_Initialize" and "APP_Tasks" prototypes) and some of them are only used
    internally by the application (such as the "APP_STATES" definition).  Both
    are defined here for convenience.
*******************************************************************************/

//DOM-IGNORE-BEGIN
/*******************************************************************************
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(INCLUDING BUT NOT LIMITED TO ANY DEFENSE THEREOF), OR OTHER SIMILAR COSTS.
 *******************************************************************************/
//DOM-IGNORE-END

#ifndef _COMMUNICATORAPP_H
#define _COMMUNICATORAPP_H

// *****************************************************************************
// *****************************************************************************
// Section: Included Files
// *****************************************************************************
// *****************************************************************************

#include <stdint.h>
#include <stdbool.h>
#include <stddef.h>
#include <stdlib.h>
#include "system_config.h"
#include "system_definitions.h"
#include "M2M_interface.h"
```

```
// DOM-IGNORE-BEGIN
#ifdef __cplusplus  // Provide C++ Compatibility

extern "C" {

#endif
// DOM-IGNORE-END

// *****************************************************************************
// *****************************************************************************
// Section: Type Definitions
// *****************************************************************************
// *****************************************************************************

// *****************************************************************************
/* Application states

  Summary:
    Application states enumeration

  Description:
    This enumeration defines the valid application states.  These states
    determine the behavior of the application at various times.
*/

typedef enum
{
      /* Application's state machine's initial state. */
      COMMUNICATORAPP_WAIT_INIT=0,
      COMMUNICATORAPP_WAIT_FOR_IP,
    COMMUNICATORAPP_WAIT_FOR_CONNECTION,
    COMMUNICATORAPP_IDLE

      /* TODO: Define states used by the application state machine. */

} COMMUNICATORAPP_STATES;


// *****************************************************************************
/* Application Data

  Summary:
    Holds application data

  Description:
    This structure holds the application's data.

  Remarks:
    Application strings and buffers are be defined outside this structure.
 */

typedef struct
{
    /* The application's current state */
    COMMUNICATORAPP_STATES state;

    IPV4_ADDR    dwLastIP;
    IPV4_ADDR DataServerIP;
    UDP_PORT DataServerPort;
    UDP_PORT DVSplatformUDPServerPort;
    UDP_PORT DVSplatformTCPServerPort;
    UDP_SOCKET UDPServerSocketHandle;
    UDP_SOCKET TCPServerSocketHandle;
    uint16_t DataLength;
```

```
    uint32_t PacketsSent;
    uint32_t PacketsReceived;
    uint8_t *DataPtr;
    uint8_t RemoteCommandBuff[4096];
    int8_t TxBuff[512];
    union
    {
        struct
        {
            uint32_t TxDataReady:1;
            uint32_t EnableTelemetryUDP:1;
            uint32_t EnableTelemetryConsole:1;
        };
        uint32_t Word;
    } Flags;

    /* TODO: Define any additional data used by the application. */

} COMMUNICATORAPP_DATA;


// *****************************************************************************
// *****************************************************************************
// Section: Application Callback Routines
// *****************************************************************************
// *****************************************************************************
/* These routines are called by drivers when certain events occur.
*/

// *****************************************************************************
// *****************************************************************************
// Section: Application Initialization and State Machine Functions
// *****************************************************************************
// *****************************************************************************

/*******************************************************************************
  Function:
    void COMMUNICATORAPP_Initialize ( void )

  Summary:
     MPLAB Harmony application initialization routine.

  Description:
    This function initializes the Harmony application.  It places the
    application in its initial state and prepares it to run so that its
    APP_Tasks function can be called.

  Precondition:
    All other system initialization routines should be called before calling
    this routine (in "SYS_Initialize").

  Parameters:
    None.

  Returns:
    None.

  Example:
    <code>
    COMMUNICATORAPP_Initialize();
    </code>

  Remarks:
    This routine must be called from the SYS_Initialize function.
```

```
*/

void COMMUNICATORAPP_Initialize ( void );


/*******************************************************************************
  Function:
    void COMMUNICATORAPP_Tasks ( void )

  Summary:
    MPLAB Harmony Demo application tasks function

  Description:
    This routine is the Harmony Demo application's tasks function.  It
    defines the application's state machine and core logic.

  Precondition:
    The system and application initialization ("SYS_Initialize") should be
    called before calling this.

  Parameters:
    None.

  Returns:
    None.

  Example:
    <code>
    COMMUNICATORAPP_Tasks();
    </code>

  Remarks:
    This routine must be called from SYS_Tasks() routine.
 */

void COMMUNICATORAPP_Tasks( void );


#endif /* _COMMUNICATORAPP_H */

//DOM-IGNORE-BEGIN
#ifdef __cplusplus
}
#endif
//DOM-IGNORE-END

/*******************************************************************************
 End of File
 */
```

Fails “igusD1.c”

```
#include "igusD1.h"

#define IGUSD1_POSITIONING_MODE_ABSOLUTE 0
#define IGUSD1_POSITIONING_MODE_RELATIVE 1


typedef struct
{
    void* ControlwordPtr;

    CO_OBJECT *Settings;
} IGUSD1_INIT_DATA;




void IGUSD1_Initialize( IGUSD1_t *id,
                        int8_t nodeId,
                        CO_OBJECT *settings,
                        void* ControlwordPtr,
                        void* StatuswordPtr,
                        void* TargetPosPtr)
{
    id->Status = IGUSD1_Init;
    id->Tag = nodeId;
    id->Controlword = ControlwordPtr;
    id->StatusWord = StatuswordPtr;
    id->TargetPos = TargetPosPtr;
    id->Settings = settings;
    id->CANnodeID = nodeId;
    id->ErrorCount = 0;
    id->SettingCount = IGUSD1_SETTING_CO_OBJECT_COUNT;
    memset(id->ProcessTimers, 0, IGUSD1_PROCESS_TIMER_COUNT * sizeof(uint32_t));
}

void IGUSD1_SetPos(IGUSD1_t *id, int32_t pos)
{
    if (id->Status == IGUSD1_ServiceTasks)
    {
        id->Controlword->SwitchOn = 1;
        id->Controlword->EnableVoltage = 1;
        id->Controlword->QuickStop = 1;
        id->Controlword->EnableOperation = 1;
        id->Controlword->StartMove = 0;     /* Do not start yet, data adoption by
                                             * IGUSD1 takes time, starting performed
                                             * in IGUSD1_Tasks function */
        id->Controlword->PositioningMode = IGUSD1_POSITIONING_MODE_ABSOLUTE;
        id->ProcessTimers[0] = 0;
        *id->TargetPos = pos;
        id->Status = IGUSD1_MoveTest;
    }
}

bool IGUSD1_IsTargetReached(IGUSD1_t *id)
{
    bool ret = false;
    if (id->Status == IGUSD1_ServiceTasks && id->StatusWord->TargetReached)
    {
        ret = true;
    }
    return ret;
```

```
}

//Works only after power up
void IGUSD1_StartHoming(IGUSD1_t *id)
{
    id->Flags.HomingRequired = 1;
}

void IGUSD1_Tasks(IGUSD1_t *id, uint32_t elapsedMiliSec)
{
    CANOPENAPP_SDO_ClientOpeResult_t res;
    int i;
    for (i = 0; i < IGUSD1_PROCESS_TIMER_COUNT; i++)
    {
        id->ProcessTimers[i] += elapsedMiliSec;
    }
    switch(id->Status)
    {
        case IGUSD1_Init:
            id->Flags.HomingRequired = 1;
            id->Status = IGUSD1_InitSetup;
        case IGUSD1_InitSetup:
            if (id->ProcessTimers[1] < 1000)
                break;
            if (id->Flags.HomingRequired)
            {
                id->Settings[1].Value = 6;  //Homing mode
            }
            else
            {
                id->Settings[1].Value = 1;  //Profile Position Mode
            }
        case IGUSD1_Setup:
            if (CANOPENAPP_TRANSFER_Initiate(   id->CANnodeID,
                                                id->Settings,
                                                id->SettingCount,
                                                CANOPENAPP_SDO_TRANSFER_DOWNLOAD, true) ==
                                        CANOPENAPP_SDO_ClientOpeScheduled)
                id->Status = IGUSD1_ConfigSetting;
            break;
        case IGUSD1_ConfigSetting:
            res = CANOPENAPP_TRANSFER_Result(id->Settings);
            switch (res)
            {
                case CANOPENAPP_SDO_ClientOpeResultOK:
                    SYS_CONSOLE_PRINT("IGUS D1 [%d]: ", id->Tag);
                    SYS_CONSOLE_PRINT("Enabling voltage\r\n");
                    id->Controlword->EnableVoltage = 1;
                    id->Controlword->QuickStop = 1;         /*Send control word Enable
voltage
                                                             * and Quick stop to enter
                                                             * "Ready to switch on" state
*/
                    id->Status = IGUSD1_EnablingVoltage;
                    break;
                case CANOPENAPP_SDO_ClientCANerror:
                case CANOPENAPP_SDO_ClientArgError:
                    id->Status = IGUSD1_Error;
                    break;
                case CANOPENAPP_SDO_ClientOpeScheduled:
                default:
                    break;
            }
            break;
```

```c
case IGUSD1_EnablingVoltage:
    if (id->StatusWord->ReadyToSwitchOn)
    {
        SYS_CONSOLE_PRINT("IGUS D1 [%d]: ", id->Tag);
        SYS_CONSOLE_PRINT("Switching on\r\n");
        id->Controlword->SwitchOn = 1;
        id->Controlword->EnableVoltage = 1;
        id->Controlword->QuickStop = 1;          /*Send control word Enable voltage
                                                  * and Quick stop
                                                  * and Switch on to enter
                                                  * "Switched on" state */
        id->Status = IGUSD1_SwitchingOn;
    }
    //TODO: else add timeout?
    break;
case IGUSD1_SwitchingOn:
    if (id->StatusWord->SwitchedOn)
    {
        SYS_CONSOLE_PRINT("IGUS D1 [%d]: ", id->Tag);
        SYS_CONSOLE_PRINT("Enabling operation\r\n");
        id->Controlword->SwitchOn = 1;
        id->Controlword->EnableVoltage = 1;
        id->Controlword->EnableOperation = 1;
        id->Controlword->QuickStop = 1;          /*Send control word Enable voltage
                                                  * and Quick stop
                                                  * and Switch on
                                                  * and Enable operation to enter
                                                  * "Operation enabled" state */
        id->Status = IGUSD1_EnablingOperation;
    }
    break;
case IGUSD1_EnablingOperation:
    if (id->StatusWord->OperationEnabled)
    {
        if (id->Flags.HomingRequired)
        {
            SYS_CONSOLE_PRINT("IGUS D1 [%d]: ", id->Tag);
            SYS_CONSOLE_PRINT("Homing starting\r\n");
            id->Status = IGUSD1_HomingStarting;
            id->ProcessTimers[0] = 0;
            id->Flags.HomingRequired = 0;
        }
        else
        {
            SYS_CONSOLE_PRINT("IGUS D1 [%d]: ", id->Tag);
            SYS_CONSOLE_PRINT("Operation enabled\r\n");
            id->Status = IGUSD1_ServiceTasks;
        }
    }
    break;
case IGUSD1_ServiceTasks:
    if (id->Flags.HomingRequired)
    {
        id->Status = IGUSD1_InitSetup;
    }
    break;
case IGUSD1_HomingStarting:
    if (id->ProcessTimers[0] > 10)
    {
        id->Controlword->SwitchOn = 1;
        id->Controlword->EnableVoltage = 1;
        id->Controlword->QuickStop = 1;
        id->Controlword->EnableOperation = 1;
        id->Controlword->StartMove = 1;      //Start of homing movement
```

```
            id->ProcessTimers[0] = 0;
            id->Status = IGUSD1_HomingProgress;
        }
        break;
    case IGUSD1_HomingProgress:
        if (id->ProcessTimers[0] < 50)
            break;
        if (id->StatusWord->TargetReached)
        {
            id->Controlword->StartMove = 0;
            SYS_CONSOLE_PRINT("IGUS D1 [%d]: ", id->Tag);
            SYS_CONSOLE_PRINT("Homing complete\r\n");
            id->Status = IGUSD1_InitSetup;      //Setup normal operation after homing
        }
        break;
    case IGUSD1_MoveTest:
        if (id->ProcessTimers[0] > 10)
        {
            id->Controlword->StartMove = 1;     //Start of movement
            id->ProcessTimers[0] = 0;
            id->Status = IGUSD1_Moving;
        }
        break;
    case IGUSD1_Moving:
        if (id->StatusWord->SetpointApplied == 1)
        {
            id->Controlword->StartMove = 0;
        }
        if (id->ProcessTimers[0] > 10)
        {
            id->Controlword->StartMove = 0;
            if (id->StatusWord->TargetReached == 1)
            {
                id->Status = IGUSD1_ServiceTasks;
            }
        }
        break;
    case IGUSD1_Error:
        if (id->ErrorCount < 100)
        {
            SYS_CONSOLE_PRINT("IGUS D1 [%d]: ", id->Tag);
            SYS_CONSOLE_PRINT("CAN open error, attempt to continue\n\r");
            id->ErrorCount++;
            id->Status = IGUSD1_ServiceTasks;
        }
        else if (id->ErrorCount == 100)
        {
            SYS_CONSOLE_PRINT("IGUS D1 [%d]: ", id->Tag);
            SYS_CONSOLE_PRINT("No response\n\r");
            id->ErrorCount++;
        }
        break;
    }
}
```

Fails “igusD1.h”

```
/*
 * File:   igusD1.h
 * Author: Vitalijs
 *
 * Created on otrdiena, 2020, 14 j?lijs, 12:22
 */

#ifndef IGUSD1_H
#define     IGUSD1_H

#ifdef      __cplusplus
extern "C" {
#endif

#include <stdint.h>
#include <string.h>
#include <stddef.h>
#include <errno.h>
#include "system_definitions.h"
#include "system_config.h"
#include "osal/osal.h"

#define IGUSD1_SETTING_CO_OBJECT_COUNT 10
#define IGUSD1_PROCESS_TIMER_COUNT 2

typedef enum
{
    IGUSD1_Init = 0,
    IGUSD1_InitSetup,
    IGUSD1_Setup,
    IGUSD1_ConfigSetting,
    IGUSD1_EnablingVoltage,
    IGUSD1_SwitchingOn,
    IGUSD1_EnablingOperation,
    IGUSD1_ServiceTasks,
    IGUSD1_MoveTest,
    IGUSD1_Moving,
    IGUSD1_HomingStarting,
    IGUSD1_HomingProgress,
    IGUSD1_Error
} IGUSD1_STATUS;

typedef struct
{
    uint16_t SwitchOn:1;
    uint16_t EnableVoltage:1;
    uint16_t QuickStop:1;
    uint16_t EnableOperation:1;
    uint16_t StartMove:1;
    uint16_t ModeSpec2:1;
    uint16_t PositioningMode:1;
    uint16_t FaultReset:1;
    uint16_t Halt:1;
    uint16_t ModeSpec4:1;
    uint16_t :6;
} IGUSD1_CONTROLWORD;

typedef struct
{
    uint16_t ReadyToSwitchOn:1;
    uint16_t SwitchedOn:1;
    uint16_t OperationEnabled:1;
```

```c
    uint16_t Fault:1;
    uint16_t VoltageEnable:1;
    uint16_t QuickStop:1;
    uint16_t SwitchOnDisabled:1;
    uint16_t Warning:1;
    uint16_t :1;
    uint16_t Remote:1;
    uint16_t TargetReached:1;
    uint16_t InternalLimitActive:1;
    uint16_t SetpointApplied:1;
    uint16_t :3;

} IGUSD1_STATUSWORD;

typedef struct
{
    IGUSD1_STATUS Status;
    int32_t Tag;
    IGUSD1_CONTROLWORD *Controlword;
    IGUSD1_STATUSWORD *StatusWord;
    uint8_t CANnodeID;

    int32_t *TargetPos;
    CO_OBJECT *Settings;
    uint32_t CurrSetting;
    uint32_t SettingCount;
    uint32_t ErrorCount;

    uint32_t ProcessTimers[IGUSD1_PROCESS_TIMER_COUNT];
    struct
    {
        uint32_t HomingRequired:1;
    } Flags;
} IGUSD1_t;

void IGUSD1_Initialize( IGUSD1_t *id,
                        int8_t nodeId,
                        CO_OBJECT *settings,
                        void* ControlwordPtr,
                        void* StatuswordPtr,
                        void* TargetPosPtr);
void IGUSD1_Tasks(IGUSD1_t *id, uint32_t elapsedMiliSec);
void IGUSD1_SetPos(IGUSD1_t *id, int32_t pos);
void IGUSD1_ReadCANobj(uint16_t address, uint16_t subIdx);
void IGUSD1_StartHoming(IGUSD1_t *id);
bool IGUSD1_IsTargetReached(IGUSD1_t *id);


#ifdef      __cplusplus
}
#endif

#endif      /* IGUSD1_H */
```

Fails "main.c"

```
/*******************************************************************************
  MPLAB Harmony Project Main Source File

  Company:
    Microchip Technology Inc.

  File Name:
    main.c

  Summary:
    This file contains the "main" function for an MPLAB Harmony project.

  Description:
    This file contains the "main" function for an MPLAB Harmony project.  The
    "main" function calls the "SYS_Initialize" function to initialize the state
    machines of all MPLAB Harmony modules in the system and it calls the
    "SYS_Tasks" function from within a system-wide "super" loop to maintain
    their correct operation. These two functions are implemented in
    configuration-specific files (usually "system_init.c" and "system_tasks.c")
    in a configuration-specific folder under the "src/system_config" folder
    within this project's top-level folder.  An MPLAB Harmony project may have
    more than one configuration, each contained within it's own folder under
    the "system_config" folder.
 *******************************************************************************/

// DOM-IGNORE-BEGIN
/*******************************************************************************
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SUBSTITUTE GOODS, TECHNOLOGY, SERVICES, OR ANY CLAIMS BY THIRD PARTIES
(INCLUDING BUT NOT LIMITED TO ANY DEFENSE THEREOF), OR OTHER SIMILAR COSTS.
 *******************************************************************************/
// DOM-IGNORE-END


// *****************************************************************************
// *****************************************************************************
// Section: Included Files
// *****************************************************************************
// *****************************************************************************

#include <stddef.h>                     // Defines NULL
#include <stdbool.h>                    // Defines true
#include <stdlib.h>                     // Defines EXIT_FAILURE
#include "system/common/sys_module.h"
#include "RONINCommandProc.h"   // SYS function prototypes
```

```c
// *****************************************************************************
// *****************************************************************************
// Section: Main Entry Point
// *****************************************************************************
// *****************************************************************************

void delay_1ms(void)
{
    int i = 40000;
    while(i--);
}

void delay_ms(int ms)
{
    while(ms--)
    {
        delay_1ms();
    }
}

int main ( void )
{

    /* Initialize all MPLAB Harmony modules, including application(s). */
    SYS_Initialize ( NULL );

    delay_ms(2000);

    while ( true )
    {
        /* Maintain state machines of all polled MPLAB Harmony modules. */
        SYS_Tasks ( );

    }

    /* Execution should not come here during normal operation */

    return ( EXIT_FAILURE );
}


/*******************************************************************************
 End of File
*/
```

Fails "Ronin_CNC.c"

```
#include "RONIN_CNC.h"
#include "system_config.h"
#include "system_definitions.h"
#include "igusD1.h"
#include "UDPComm/PIC32_Harmony/udpcomm.h"
#include "RONIN_laser.h"



/************************************/
/*********IgusD1 init data ***********/
/************************************/
int8_t IgusD1NodeIds[] = { 1, 2, 3, 4, 5, 6};

#define RONINCANC_AXIS_COUNT sizeof(IgusD1NodeIds)

CO_OBJECT AxisSettings[RONINCANC_AXIS_COUNT][IGUSD1_SETTING_CO_OBJECT_COUNT] =
{
    {
        { 0x1801, 5, 255, sizeof(uint16_t) },   //Communication parameter (send on demand)
        { 0x6060, 0, 1, sizeof(uint8_t) },      //Profile position mode
        { 0x6081, 0, 200, sizeof(uint32_t) },   //Profile velocity (mm/s)
        { 0x6083, 0, 200, sizeof(uint32_t) },   //Profile acceleration (mm/s^2)
        { 0x6084, 0, 200, sizeof(uint32_t) },   //Profile deceleration (mm/s^2)
        { 0x6092, 1, 70, sizeof(uint32_t) },    //Feed rate (mm)
        { 0x6092, 2, 1, sizeof(uint32_t) },     //Shaft revolutions
        { 0x6099, 1, 5, sizeof(uint32_t) },     //Switch Search Speed  (mm/s)
        { 0x6099, 2, 5, sizeof(uint32_t) },     //Zero Search Speed  (mm/s)
        { 0x609A, 0, 5, sizeof(uint32_t) },     //Homing acceleration/deceleration
(mm/s^2)
    },
    {
        { 0x1801, 5, 255, sizeof(uint16_t) },   //Communication parameter (send on demand)
        { 0x6060, 0, 1, sizeof(uint8_t) },      //Profile position mode
        { 0x6081, 0, 25, sizeof(uint32_t) },   //Profile velocity (mm/s)
        { 0x6083, 0, 25, sizeof(uint32_t) },   //Profile acceleration (mm/s^2)
        { 0x6084, 0, 200, sizeof(uint32_t) },   //Profile deceleration (mm/s^2)
        { 0x6092, 1, 70, sizeof(uint32_t) },    //Feed rate (mm)
        { 0x6092, 2, 1, sizeof(uint32_t) },     //Shaft revolutions
        { 0x6099, 1, 5, sizeof(uint32_t) },     //Switch Search Speed  (mm/s)
        { 0x6099, 2, 5, sizeof(uint32_t) },     //Zero Search Speed  (mm/s)
        { 0x609A, 0, 5, sizeof(uint32_t) },     //Homing acceleration/deceleration
(mm/s^2)
    },
    {
        { 0x1801, 5, 255, sizeof(uint16_t) },   //Communication parameter (send on demand)
        { 0x6060, 0, 1, sizeof(uint8_t) },      //Profile position mode
        { 0x6081, 0, 200, sizeof(uint32_t) },   //Profile velocity (mm/s)
        { 0x6083, 0, 200, sizeof(uint32_t) },   //Profile acceleration (mm/s^2)
        { 0x6084, 0, 200, sizeof(uint32_t) },   //Profile deceleration (mm/s^2)
        { 0x6092, 1, 70, sizeof(uint32_t) },    //Feed rate (mm)
        { 0x6092, 2, 1, sizeof(uint32_t) },     //Shaft revolutions
        { 0x6099, 1, 5, sizeof(uint32_t) },     //Switch Search Speed  (mm/s)
        { 0x6099, 2, 5, sizeof(uint32_t) },     //Zero Search Speed  (mm/s)
        { 0x609A, 0, 5, sizeof(uint32_t) },     //Homing acceleration/deceleration
(mm/s^2)
    },
    {
        { 0x1801, 5, 255, sizeof(uint16_t) },   //Communication parameter (send on demand)
        { 0x6060, 0, 1, sizeof(uint8_t) },      //Profile position mode
        { 0x6081, 0, 50, sizeof(uint32_t) },   //Profile velocity (mm/s)
        { 0x6083, 0, 100, sizeof(uint32_t) },   //Profile acceleration (mm/s^2)
```

```
        { 0x6084, 0, 100, sizeof(uint32_t) },   //Profile deceleration (mm/s^2)
        { 0x6092, 1, 70, sizeof(uint32_t) },    //Feed rate (mm)
        { 0x6092, 2, 1, sizeof(uint32_t) },     //Shaft revolutions
        { 0x6099, 1, 5, sizeof(uint32_t) },     //Switch Search Speed  (mm/s)
        { 0x6099, 2, 5, sizeof(uint32_t) },     //Zero Search Speed  (mm/s)
        { 0x609A, 0, 5, sizeof(uint32_t) },     //Homing acceleration/deceleration
(mm/s^2)
    },
    {
        { 0x1801, 5, 255, sizeof(uint16_t) },   //Communication parameter (send on demand)
        { 0x6060, 0, 1, sizeof(uint8_t) },      //Profile position mode
        { 0x6081, 0, 40, sizeof(uint32_t) },   //Profile velocity (mm/s)
        { 0x6083, 0, 100, sizeof(uint32_t) },   //Profile acceleration (mm/s^2)
        { 0x6084, 0, 100, sizeof(uint32_t) },   //Profile deceleration (mm/s^2)
        { 0x6092, 1, 70, sizeof(uint32_t) },    //Feed rate (mm)
        { 0x6092, 2, 1, sizeof(uint32_t) },     //Shaft revolutions
        { 0x6099, 1, 5, sizeof(uint32_t) },     //Switch Search Speed  (mm/s)
        { 0x6099, 2, 5, sizeof(uint32_t) },     //Zero Search Speed  (mm/s)
        { 0x609A, 0, 5, sizeof(uint32_t) },     //Homing acceleration/deceleration
(mm/s^2)
    },
    {
        { 0x1801, 5, 255, sizeof(uint16_t) },   //Communication parameter (send on demand)
        { 0x6060, 0, 1, sizeof(uint8_t) },      //Profile position mode
        { 0x6081, 0, 50, sizeof(uint32_t) },   //Profile velocity (mm/s)
        { 0x6083, 0, 100, sizeof(uint32_t) },   //Profile acceleration (mm/s^2)
        { 0x6084, 0, 100, sizeof(uint32_t) },   //Profile deceleration (mm/s^2)
        { 0x6092, 1, 70, sizeof(uint32_t) },    //Feed rate (mm)
        { 0x6092, 2, 1, sizeof(uint32_t) },     //Shaft revolutions
        { 0x6099, 1, 5, sizeof(uint32_t) },     //Switch Search Speed  (mm/s)
        { 0x6099, 2, 5, sizeof(uint32_t) },     //Zero Search Speed  (mm/s)
        { 0x609A, 0, 5, sizeof(uint32_t) },     //Homing acceleration/deceleration
(mm/s^2)
    }
};

void *COPointers[RONINCANC_AXIS_COUNT][3] =
{
    {
        (void*)&CO_OD_RAM.IGUS_D1Controlword1,
        (void*)&CO_OD_RAM.IGUS_D1Statusword1,
        (void*)&CO_OD_RAM.IGUS_D1TargetPosition1,
    },
    {
        (void*)&CO_OD_RAM.IGUS_D1Controlword2,
        (void*)&CO_OD_RAM.IGUS_D1Statusword2,
        (void*)&CO_OD_RAM.IGUS_D1TargetPosition2,
    },
    {
        (void*)&CO_OD_RAM.IGUS_D1Controlword3,
        (void*)&CO_OD_RAM.IGUS_D1Statusword3,
        (void*)&CO_OD_RAM.IGUS_D1TargetPosition3,
    },
    {
        (void*)&CO_OD_RAM.IGUS_D1Controlword4,
        (void*)&CO_OD_RAM.IGUS_D1Statusword4,
        (void*)&CO_OD_RAM.IGUS_D1TargetPosition4,
    },
    {
        (void*)&CO_OD_RAM.IGUS_D1Controlword5,
        (void*)&CO_OD_RAM.IGUS_D1Statusword5,
        (void*)&CO_OD_RAM.IGUS_D1TargetPosition5,
    },
    {
```

```
        (void*)&CO_OD_RAM.IGUS_D1Controlword6,
        (void*)&CO_OD_RAM.IGUS_D1Statusword6,
        (void*)&CO_OD_RAM.IGUS_D1TargetPosition6,
    }
};
/***********************************/

#define RONINCANC_MILISECOND_TIMER_MAX 0xFFFFFFFF

#define RONINCANC_MAX_LASERPOINTS 1024

typedef struct
{
    int32_t X;
    int32_t Y;
    int32_t Z;
    struct
    {
        /* If 1, laser will be on when heading to this point */
        uint32_t LaserOn:1;
    } Flags;
} RONINCANC_LASERPOINT;

typedef enum
{
    RONINCANC_Init = 0,
    RONINCANC_SetupAxis,
    RONINCANC_ServiceTasks
} RONINCANC_STATUS;

typedef struct
{
    IGUSD1_t AxisMotors[RONINCANC_AXIS_COUNT];
    uint32_t MilisecondTimer;
    SYS_TMR_HANDLE Tmr1msHandle;
    RONINCANC_LASERPOINT TotalPoints[RONINCANC_MAX_LASERPOINTS];
    uint32_t PointCount;
    uint32_t CurrentPoint;
    RONINCANC_STATUS Status;
    struct
    {
        uint32_t LaserAxisMoveStart:1;
        uint32_t MillAxisMoveStart:1;
    } Flags;
} RONINCANC_DATA;

RONINCANC_DATA _tcnc;
void RONINCNC_Tmr1ms_Callback ( uintptr_t context, uint32_t currTick );

void RONINCNC_Tmr1ms_Callback ( uintptr_t context, uint32_t currTick )
{
    _tcnc.MilisecondTimer++;
}

void RONINCNC_Initialize(void)
{
    _tcnc.MilisecondTimer = 0;
    _tcnc.Tmr1msHandle = DRV_HANDLE_INVALID;
    _tcnc.Status = RONINCANC_Init;
    _tcnc.CurrentPoint = 0;
    _tcnc.PointCount = 0;
    _tcnc.Flags.LaserAxisMoveStart = 0;
    _tcnc.Flags.MillAxisMoveStart = 0;
}
```

```
void _addLaserPoint(int32_t x, int32_t y, int32_t z, bool powerOn)
{
    if (_tcnc.PointCount < RONINCANC_MAX_LASERPOINTS)
    {
        _tcnc.TotalPoints[_tcnc.PointCount].X = x;
        _tcnc.TotalPoints[_tcnc.PointCount].Y = y;
        _tcnc.TotalPoints[_tcnc.PointCount].Z = z;
        if (powerOn)
            _tcnc.TotalPoints[_tcnc.PointCount].Flags.LaserOn = 1;
        else
            _tcnc.TotalPoints[_tcnc.PointCount].Flags.LaserOn = 0;
        _tcnc.PointCount++;
    }
}

void RONINCNC_SetLaserPos(int32_t x, int32_t y, int32_t z)
{
    if (_tcnc.PointCount == 0)
    {
        _tcnc.CurrentPoint = 0;
        _addLaserPoint(x, y, z, false);
    }
}

void _setLaserPos(int32_t x, int32_t y, int32_t z)
{
    IGUSD1_SetPos(&(_tcnc.AxisMotors[0]), x);
    IGUSD1_SetPos(&(_tcnc.AxisMotors[1]), y);
    IGUSD1_SetPos(&(_tcnc.AxisMotors[2]), z);
    _tcnc.Flags.LaserAxisMoveStart = 1;
}

void RONINCNC_SetMillPos(int32_t x, int32_t y, int32_t z)
{
    _setMillPos(x, y, z);
}

void _setMillPos(int32_t x, int32_t y, int32_t z)
{
    IGUSD1_SetPos(&(_tcnc.AxisMotors[3]), x);
    IGUSD1_SetPos(&(_tcnc.AxisMotors[4]), y);
    IGUSD1_SetPos(&(_tcnc.AxisMotors[5]), z);
    _tcnc.Flags.MillAxisMoveStart = 1;
}

/*
 * Draw rectangle with laser on at constant height z
 *  x,y -> x+w,y
 *  x+w -> x+w,y+h
 *  x+w,y+h -> x,y+h
 *  x,y+h -> x,y
 */
void RONINCNC_DrawLaserPattern1(int32_t x, int32_t y, int32_t z, int32_t w, int32_t h)
{
    if (_tcnc.PointCount == 0)
    {
        _tcnc.CurrentPoint = 0;
        _addLaserPoint(x, y, z, false);
        _addLaserPoint(x, y + h, z, true);
        _addLaserPoint(x + w, y + h, z, true);
        _addLaserPoint(x + w, y, z, true);
        _addLaserPoint(x, y, z, true);
        _addLaserPoint(x, y, z, false);
```

```
    }
}

#define PATTERN2_STEP 3

void RONINCNC_DrawLaserPattern2(int32_t x, int32_t y, int32_t z, int32_t w, int32_t h)
{
    int32_t hSum = 0;
    if (_tcnc.PointCount == 0)
    {
        _tcnc.CurrentPoint = 0;
        _addLaserPoint(x, y, z, false);     //Move to start (laser off)


        while (hSum < h)
        {
            hSum += PATTERN2_STEP;
            _addLaserPoint(x + w, y + hSum, z, true);   //to the right (laser on)
            _addLaserPoint(x, y + hSum, z, true);   //to the left (laser on)
        }
        _addLaserPoint(x, y + hSum, z, false);      //turn off laser
    }
}

void RONINCNC_Tasks(void)
{
    int i;
    static int currAxis = 0;
    static uint32_t prevTime = 0;
    //New time difference after last call
    uint32_t timeDiff = _tcnc.MilisecondTimer
                        + RONINCANC_MILISECOND_TIMER_MAX - prevTime + 1;
    prevTime = _tcnc.MilisecondTimer;
    switch (_tcnc.Status)
    {
        case RONINCANC_Init:
            if (SYS_TMR_Status(sysObj.sysTmr) == SYS_STATUS_READY && (UDPCOMM_GetState()
== UDPCOMM_READY))
            {
                if (_tcnc.Tmr1msHandle == DRV_HANDLE_INVALID)
                    _tcnc.Tmr1msHandle = SYS_TMR_CallbackPeriodic(1, 0,
&RONINCNC_Tmr1ms_Callback);
                if (_tcnc.Tmr1msHandle == DRV_HANDLE_INVALID)
                    break;
                for (i = 0; i < RONINCANC_AXIS_COUNT; i++)
                {
                    IGUSD1_Initialize(&(_tcnc.AxisMotors[i]), IgusD1NodeIds[i],
AxisSettings[i], COPointers[i][0], COPointers[i][1], COPointers[i][2]);
                    IGUSD1_StartHoming(&(_tcnc.AxisMotors[i]));
                }
                RONIN_LASER_Initialize();
                RONIN_MILL_Initialize();
                _tcnc.Status = RONINCANC_SetupAxis;
            }
            break;
        case RONINCANC_SetupAxis:
            _tcnc.Status = RONINCANC_ServiceTasks;
            break;
        case RONINCANC_ServiceTasks:

            if (!_tcnc.Flags.LaserAxisMoveStart)
            {
                if (_tcnc.CurrentPoint < _tcnc.PointCount)
                {
```

```
                    _setLaserPos(
                            _tcnc.TotalPoints[_tcnc.CurrentPoint].X,
                            _tcnc.TotalPoints[_tcnc.CurrentPoint].Y,
                            _tcnc.TotalPoints[_tcnc.CurrentPoint].Z);
                    if (_tcnc.TotalPoints[_tcnc.CurrentPoint].Flags.LaserOn)
                        RONIN_LASER_Enable();
                    else
                        RONIN_LASER_Disable();
                }
            }

            if (_tcnc.Flags.LaserAxisMoveStart)
            {
                if (    IGUSD1_IsTargetReached(&(_tcnc.AxisMotors[0])) &&
                        IGUSD1_IsTargetReached(&(_tcnc.AxisMotors[1])) &&
                        IGUSD1_IsTargetReached(&(_tcnc.AxisMotors[2])))
                {
                    _tcnc.Flags.LaserAxisMoveStart = 0;
                    _tcnc.CurrentPoint++;
                    if (_tcnc.CurrentPoint == _tcnc.PointCount)
                    {
                        _tcnc.CurrentPoint = 0;
                        _tcnc.PointCount = 0;

RONIN_COMMAND_PROC_ReplyPatternOk(RONIN_RequestPatternCompleteLaser);
                    }
                }
            }
            if (_tcnc.Flags.MillAxisMoveStart)
            {
                if (    IGUSD1_IsTargetReached(&(_tcnc.AxisMotors[3])) &&
                        IGUSD1_IsTargetReached(&(_tcnc.AxisMotors[4])) &&
                        IGUSD1_IsTargetReached(&(_tcnc.AxisMotors[5])))
                {
                    RONIN_COMMAND_PROC_ReplyPatternOk(RONIN_RequestPatternCompleteMill);
                    _tcnc.Flags.MillAxisMoveStart = 0;
                }
            }
            for (i = 0; i < RONINCANC_AXIS_COUNT; i++)
            {
                IGUSD1_Tasks(&_tcnc.AxisMotors[i], timeDiff);
            }
            RONIN_LASER_Tasks();
            RONIN_MILL_Tasks();
            break;
    }
}
```

Fails “Ronin_CNC.h”

```
/*
 * File:   RONIN_CNC.h
 * Author: Vitalijs
 *
 * Created on tre?diena, 2020, 12 augusts, 08:45
 */

#ifndef RONIN_CNC_H
#define     RONIN_CNC_H

#ifdef      __cplusplus
extern "C" {
#endif

#include <stdint.h>
#include <stdbool.h>
#include "system_config.h"
#include "system_definitions.h"

void RONINCNC_Initialize(void);
void RONINCNC_Tasks(void);

void RONINCNC_SetLaserPos(int32_t x, int32_t y, int32_t z);
void RONINCNC_SetMillPos(int32_t x, int32_t y, int32_t z);
void RONINCNC_DrawLaserPattern1(int32_t x, int32_t y, int32_t z, int32_t w, int32_t h);
void RONINCNC_DrawLaserPattern2(int32_t x, int32_t y, int32_t z, int32_t w, int32_t h);

#ifdef      __cplusplus
}
#endif

#endif      /* RONIN_CNC_H */
```

Fails “Ronin_command_proc.c”

```
#include "RONINCommandProc.h"
#include "RONIN_motor.h"
#include "RONIN_CNC.h"
#include "RONIN_laser.h"
#include "RONIN_mill.h"
#include <stdlib.h>

#define RONIN_COMMAND_WDT_PERIOD 200

#define RONIN_MOTOR_COUNT 4

#ifdef LEDRStateSet
#define  WDT_TO_LED_ON() LEDRStateSet(0)
#define  WDT_TO_LED_OFF() LEDRStateSet(1)
#endif
#ifdef BSP_LED_3On
#define  WDT_TO_LED_ON() BSP_LED_3On()
#define  WDT_TO_LED_OFF() BSP_LED_3Off()
#endif

#define MAX_TOKENS 32
const int8_t seps[] = ";";

typedef enum
{
    RONIN_INIT_READ = 0,
    RONIN_INIT_WRITE,
    RONIN_INIT_CHeck,
} RONIN_INTIT_PHASE;

typedef struct
{
    RONIN_STATE State;
    RONIN_INTIT_PHASE InitPhase;

    uint32_t CurrMotorID;
    int32_t SpeedL;
    int32_t SpeedR;
    uint32_t RPMtotal;
    uint64_t Etotal;
    uint64_t LaserTtotal;
    uint32_t LaserPower;
    uint32_t BumperStatus;
    uint32_t LaserStatus;
    uint32_t BattVolatge;
    uint32_t MotorCurrent[RONIN_MOTOR_COUNT];
    uint8_t DataBuff[32];
    SYS_TMR_HANDLE Tmr200msHandle;
    SYS_TMR_HANDLE Tmr1sHandle;
    SYS_TMR_HANDLE TmrWDTHandle;
    SIMPLE_QUEUE IncomeCommandQueue;
    SIMPLE_QUEUE ProcessedCommandQueue;
} RONIN_DATA;

int8_t *_RONIN_COMMAND_PROC_CommandStrings[] =
{

    RONIN_COMMAND_ASCII_STRINGS

};
```

```
#define RONIN_COMMAND_PROC_CMD_STR_COUNT    (sizeof(_RONIN_COMMAND_PROC_CommandStrings) /
\
                            sizeof(_RONIN_COMMAND_PROC_CommandStrings[0]))


void RONIN_COMMAND_PROC_200ms_Callback( uintptr_t context, uint32_t currTick );
void RONIN_COMMAND_PROC_1s_Callback( uintptr_t context, uint32_t currTick );
void RONIN_COMMAND_PROC_WDT_Callback( uintptr_t context, uint32_t currTick );
void RONIN_SDO_ClientOpCallback( CANOPENAPP_SDO_ClientOpeResult_t opResult);

RONIN_DATA _t;

void RONIN_COMMAND_PROC_Initialize(void)
{
    memset(&_t, 0, sizeof(RONIN_DATA));
    SimpleQueue_Init(&_t.IncomeCommandQueue);
    SimpleQueue_Init(&_t.ProcessedCommandQueue);
    _t.Tmr200msHandle = SYS_TMR_CallbackPeriodic(200, 0,
&RONIN_COMMAND_PROC_200ms_Callback);
    _t.Tmr1sHandle = SYS_TMR_CallbackPeriodic(1000, 0, &RONIN_COMMAND_PROC_1s_Callback);
    _t.TmrWDTHandle = SYS_TMR_CallbackPeriodic(RONIN_COMMAND_WDT_PERIOD, 0,
&RONIN_COMMAND_PROC_WDT_Callback);
    _t.State = RONIN_INITIALIZE;
}

void RONIN_COMMAND_PROC_WDT_Timeout(void)
{
    WDT_TO_LED_ON();
    RONIN_MOTOR_SetSpeed(RONIN_MOTOR_FL, 0);
    RONIN_MOTOR_SetSpeed(RONIN_MOTOR_RL, 0);
    RONIN_MOTOR_SetSpeed(RONIN_MOTOR_FR, 0);
    RONIN_MOTOR_SetSpeed(RONIN_MOTOR_RR, 0);
}

void RONIN_COMMAND_PROC_WDT_Reload(void)
{
    SYS_TMR_ObjectReload(_t.TmrWDTHandle, RONIN_COMMAND_WDT_PERIOD,
                        0, &RONIN_COMMAND_PROC_WDT_Callback);
    WDT_TO_LED_OFF();
}

void RONIN_COMMAND_PROC_WDT_Callback( uintptr_t context, uint32_t currTick )
{
    RONIN_COMMAND_PROC_WDT_Timeout();
}

void RONIN_COMMAND_PROC_200ms_Callback( uintptr_t context, uint32_t currTick )
{
    RONIN_COMMAND *comPtr;
//    comPtr = (RONIN_COMMAND*)OSAL_Malloc(sizeof(RONIN_COMMAND));
//    if (comPtr)
//    {
//        comPtr->Type = RONIN_RequestSpeed;
//        comPtr->VarCount = 2;
//        comPtr->Data[0] = _t.SpeedL;
//        comPtr->Data[1] = _t.SpeedR;
//        if (SimpleQueue_IsFull(&_t.IncomeCommandQueue))
//            RONIN_COMMAND_PROC_DisposeCommandFromQueue(&_t.IncomeCommandQueue);
//        SimpleQueue_Insert(&_t.IncomeCommandQueue, (int)comPtr);
//    }
}

void RONIN_COMMAND_PROC_1s_Callback( uintptr_t context, uint32_t currTick )
{
```

```
    RONIN_COMMAND *comPtr;
    int i;
    if (_t.BattVolatge++ > 24) _t.BattVolatge = 0;
    if (_t.BumperStatus++ > 1) _t.BumperStatus = 0;
    if (_t.LaserStatus++ > 1) _t.LaserStatus = 0;
    for (i = 0; i < 4; i++)
    {
        _t.MotorCurrent[i]++;
        if (_t.MotorCurrent[i]++ > 100) _t.MotorCurrent[i] = 0;
    }
//    comPtr = (RONIN_COMMAND*)OSAL_Malloc(sizeof(RONIN_COMMAND));
//    if (comPtr)
//    {
//        comPtr->Type = RONIN_RequestSystemStatus;
//        comPtr->VarCount = 2;
//        comPtr->Data[0] = _t.BumperStatus;
//        comPtr->Data[1] = _t.LaserStatus;
//        if (SimpleQueue_IsFull(&_t.IncomeCommandQueue))
//            RONIN_COMMAND_PROC_DisposeCommandFromQueue(&_t.IncomeCommandQueue);
//        SimpleQueue_Insert(&_t.IncomeCommandQueue, (int)comPtr);
//    }
//    comPtr = (RONIN_COMMAND*)OSAL_Malloc(sizeof(RONIN_COMMAND));
//    if (comPtr)
//    {
//        comPtr->Type = RONIN_RequestBattVoltage;
//        comPtr->VarCount = 1;
//        comPtr->Data[0] = _t.BattVolatge;
//        if (SimpleQueue_IsFull(&_t.IncomeCommandQueue))
//            RONIN_COMMAND_PROC_DisposeCommandFromQueue(&_t.IncomeCommandQueue);
//        SimpleQueue_Insert(&_t.IncomeCommandQueue, (int)comPtr);
//    }
//    comPtr = (RONIN_COMMAND*)OSAL_Malloc(sizeof(RONIN_COMMAND));
//    if (comPtr)
//    {
//        comPtr->Type = RONIN_RequestMotorCurrents;
//        comPtr->VarCount = 4;
//        for (i = 0; i < 4; i++)
//        {
//            comPtr->Data[i] = _t.MotorCurrent[i];
//        }
//        if (SimpleQueue_IsFull(&_t.IncomeCommandQueue))
//            RONIN_COMMAND_PROC_DisposeCommandFromQueue(&_t.IncomeCommandQueue);
//        SimpleQueue_Insert(&_t.IncomeCommandQueue, (int)comPtr);
//    }
}

void RONIN_SDO_ClientOpCallback( CANOPENAPP_SDO_ClientOpeResult_t opResult)
{
    if (opResult == CANOPENAPP_SDO_ClientOpeResultOK)
    {
        _t.CurrMotorID++;
        if (_t.CurrMotorID < 4)
        {
            _t.State = RONIN_INITIALIZE;
        }
        else
            _t.State = RONIN_TASKS;
    }
    else
    {
        _t.State = RONIN_ERROR;
    }
}
```

```
void RONIN_COMMAND_PROC_DisposeCommandFromQueue(SIMPLE_QUEUE *q)
{
    RONIN_COMMAND *comPtr;//TODO: pareizi izma?ana neapstr?d?tajiem?
    comPtr = (RONIN_COMMAND*)SimpleQueue_Remove(q);
    RONIN_COMMAND_PROC_DisposeCommand(comPtr);
}

void RONIN_COMMAND_PROC_ParseString(int8_t *str)
{
    size_t i = 0, tokenCount = 0;
    int8_t *tokens[MAX_TOKENS];
    int8_t *endPtr;
    int8_t radix;
    int32_t sp;
    RONIN_COMMAND *comPtr, *comPtr2;
    int32_t sign = 1;
    tokenCount = 0;
    tokens[0] = strtok(str, seps);
    while(tokens[tokenCount] != NULL)
    {
        tokens[++tokenCount] = strtok(NULL, seps);
    }
    if (tokenCount > 1)
    {
        for (i = 0; i < RONIN_COMMAND_PROC_CMD_STR_COUNT; i++)
        {
            if (!strcmp(tokens[1], _RONIN_COMMAND_PROC_CommandStrings[i])) //Check command
type
                break;      //Stop checking, if valid command recognized
        }
    }
    else
        i = RONIN_COMMAND_PROC_CMD_STR_COUNT;

    //parse strings...
    //If valid command found, handle command by inserting it into command queue
    if (i < RONIN_COMMAND_PROC_CMD_STR_COUNT)
    {
        comPtr = (RONIN_COMMAND*)OSAL_Malloc(sizeof(RONIN_COMMAND));
        if (comPtr)
        {
            errno = 0;
            comPtr->ID = strtol(tokens[0], (char**)&endPtr, 10);
            if (!errno && (tokens[0] != endPtr))
            {
                comPtr->Type = i + 1;
                for (i = 2; i < tokenCount; i++)
                {
                    errno = 0;
                    if (strchr(tokens[i], 'x'))
                        comPtr->Data[i - 2].Integer32 = strtol(tokens[i], (char**)&endPtr,
16);
                    else if (strchr(tokens[i], '.'))
                        comPtr->Data[i - 2].Floating32 = strtof(tokens[i],
(char**)&endPtr);
                    else
                        comPtr->Data[i - 2].Integer32 = strtol(tokens[i], (char**)&endPtr,
10);
                    if (errno || (tokens[i] == endPtr))
                        break;
                }
                if (i == tokenCount)
                {
```

```
                    if (SimpleQueue_IsFull(&_t.IncomeCommandQueue))

RONIN_COMMAND_PROC_DisposeCommandFromQueue(&_t.IncomeCommandQueue);
                    comPtr->VarCount = tokenCount - 2;
                    SimpleQueue_Insert(&_t.IncomeCommandQueue, (int)comPtr);
                }
                else
                {
                    RONIN_COMMAND_PROC_DisposeCommand(comPtr);
                }
            }
            else
            {
                RONIN_COMMAND_PROC_DisposeCommand(comPtr);
            }
        }
    }
    //If no valid command found, possibly command form UDP joystick
    //check if it is of type XXXXYYYYZZZZQQQQ
    //by checking length and terminating character
    //XXXX = [1000...2000], center = 1500
    else
    {
        if (strlen(str) == 16)
        {
            comPtr = (RONIN_COMMAND*)OSAL_Malloc(sizeof(RONIN_COMMAND));
            if (comPtr)
            {
                comPtr->ID = 0;
                comPtr->Type = RONIN_SetSpeed;
                //values ----YYYY----QQQQ- are used for left and right speeds
                str[8] = 0;
                str[16] = 0;
                comPtr->Data[0].Integer32 = strtol(str + 4, NULL, 10);
                if (comPtr->Data[0].Integer32 < 1600 && comPtr->Data[0].Integer32 > 1400)
                    comPtr->Data[0].Integer32 = 1500;
                comPtr->Data[0].Integer32 = (comPtr->Data[0].Integer32 - 1500);
                if (comPtr->Data[0].Integer32 < 0)
                    sign = -1;
                else
                    sign = 1;
                comPtr->Data[0].Integer32 /= -5;    //[-100...100]
                comPtr->Data[0].Integer32 = comPtr->Data[0].Integer32 * comPtr-
>Data[0].Integer32;
                comPtr->Data[0].Integer32 /= -100 * sign;


                comPtr->Data[1].Integer32 = strtol(str + 12, NULL, 10);
                if (comPtr->Data[1].Integer32 < 1600 && comPtr->Data[1].Integer32 > 1400)
                    comPtr->Data[1].Integer32 = 1500;
                comPtr->Data[1].Integer32 = (comPtr->Data[1].Integer32 - 1500);
                if (comPtr->Data[1].Integer32 < 0)
                    sign = -1;
                else
                    sign = 1;
                comPtr->Data[1].Integer32 /= -5;   //[-100...100]

                comPtr->Data[1].Integer32 = comPtr->Data[1].Integer32 * comPtr-
>Data[1].Integer32;
                comPtr->Data[1].Integer32 /= -100 * sign;

                comPtr->VarCount = 2;
                SimpleQueue_Insert(&_t.IncomeCommandQueue, (int)comPtr);
            }
```

```
        }
    }
}


void RONIN_COMMAND_PROC_DisposeCommand(RONIN_COMMAND *comPtr)
{
    OSAL_Free(comPtr);
}

void RONIN_COMMAND_PROC_Tasks(void)
{
    int i;
    RONIN_COMMAND *comPtr = NULL;
    static CO_OBJECT coObject;
    switch(_t.State)
    {
        case RONIN_INITIALIZE:
             _t.State = RONIN_TASKS;
            break;
        case RONIN_INIT_BUSY:
            break;
        case RONIN_TASKS:
            if (!SimpleQueue_IsEmpty(&_t.IncomeCommandQueue))
            {
                comPtr = (RONIN_COMMAND*)SimpleQueue_Remove(&_t.IncomeCommandQueue);
                switch(comPtr->Type)
                {
                    case RONIN_SetSpeed:
                        _t.SpeedL = comPtr->Data[0].Integer32;
                        _t.SpeedR = comPtr->Data[1].Integer32;

                        //WORKAROUND FOR SAFETY while no rotation sensors:
                        //ALways raw PWM mode
                        RONIN_MOTOR_SetControlMode(1);

                        RONIN_MOTOR_SetSpeed(RONIN_MOTOR_FL, (int16_t)comPtr-
>Data[0].Integer32);
                        RONIN_MOTOR_SetSpeed(RONIN_MOTOR_RL, (int16_t)comPtr-
>Data[0].Integer32);
                        RONIN_MOTOR_SetSpeed(RONIN_MOTOR_FR, (int16_t)(-comPtr-
>Data[1].Integer32));
                        RONIN_MOTOR_SetSpeed(RONIN_MOTOR_RR, (int16_t)(-comPtr-
>Data[1].Integer32));
                        RONIN_COMMAND_PROC_WDT_Reload();
                        break;
                    case RONIN_SetLaserCoord:
                        //RONIN_LASER_AddPointPairRange(&comPtr->Data[0], comPtr-
>VarCount);
                        RONINCNC_SetLaserPos(   comPtr->Data[0].Integer32,
                                                comPtr->Data[1].Integer32,
                                                comPtr->Data[2].Integer32);

                        break;
                    case RONIN_SetMillCoord:
                        RONINCNC_SetMillPos(    comPtr->Data[0].Integer32,
                                                comPtr->Data[1].Integer32,
                                                comPtr->Data[2].Integer32);
                        break;
                    case  RONIN_DrawPattern:
                        switch (comPtr->Data[0].Unsigned32)
                        {
                            case 1:
                                RONINCNC_DrawLaserPattern1(
```

```
                    comPtr->Data[1].Unsigned32,
                    comPtr->Data[2].Unsigned32,
                    comPtr->Data[3].Unsigned32,
                    comPtr->Data[4].Unsigned32,
                    comPtr->Data[5].Unsigned32);
            break;
        case 2:
            RONINCNC_DrawLaserPattern2(
                    comPtr->Data[1].Unsigned32,
                    comPtr->Data[2].Unsigned32,
                    comPtr->Data[3].Unsigned32,
                    comPtr->Data[4].Unsigned32,
                    comPtr->Data[5].Unsigned32);
        default:
            break;
    }
    break;
case RONIN_RequestRevStats:
    break;
case RONIN_RequestEnergyStats:
    break;
case RONIN_RequestLaserStats:
    break;
case RONIN_SetLaserPow:
    _t.LaserPower = comPtr->Data[0].Unsigned32;
    RONIN_LASER_SetPower((uint16_t)comPtr->Data[0].Unsigned32);
    break;
case RONIN_EnableLaser:
    if (comPtr->Data[0].Unsigned32)
        RONIN_LASER_Enable();
    else
        RONIN_LASER_Disable();
    break;
case RONIN_EnableMill:
    if (comPtr->Data[0].Unsigned32)
        RONIN_MILL_Enable(comPtr->Data[0].Unsigned32);
    else
        RONIN_MILL_Disable();
    break;
case RONIN_RequestLaserPow:
    break;
case RONIN_RequestSpeed:
    break;
case RONIN_RequestSystemStatus:
    break;
case RONIN_RequestBattVoltage:
    break;
case RONIN_RequestMotorCurrents:
    break;
case RONIN_SetMotorControlMode:
    if (comPtr->Data[0].Unsigned32 == 0)
    {
        //feedback mode
        RONIN_MOTOR_SetControlMode(0);
    }
    else
    {
        //raw PWM mode
        RONIN_MOTOR_SetControlMode(1);
    }
    break;
case RONIN_CNC_Ax1:
    //IGUSD1_SetPos(comPtr->Data[0]);
```

```
                        RONINCNC_SetLaserPos(comPtr->Data[0].Integer32, comPtr-
>Data[1].Integer32, 0);
                        break;
                    case RONIN_ReadCANObj:
                        coObject.Idx = (int16_t)comPtr->Data[1].Unsigned32;
                        coObject.SubIdx = (int16_t)comPtr->Data[2].Unsigned32;
                        coObject.Value = 0; //Cler data buffer, because byte array of
shorter than 4 bytes can be read
                        CANOPENAPP_TRANSFER_Initiate(   (uint8_t)comPtr-
>Data[0].Unsigned32,
                                                        &coObject,
                                                        1,
                                                        CANOPENAPP_SDO_TRANSFER_UPLOAD,
false);
                        break;
                    case RONIN_WriteCANObj:
                        //Transfer one object to given CANopen node
                        coObject.Idx = (int16_t)comPtr->Data[1].Unsigned32;
                        coObject.SubIdx = (int16_t)comPtr->Data[2].Unsigned32;
                        coObject.Value = comPtr->Data[3].Unsigned32;
                        coObject.Size = (int16_t)comPtr->Data[4].Unsigned32;
                        CANOPENAPP_TRANSFER_Initiate(   (uint8_t)comPtr-
>Data[0].Integer32,
                                                        &coObject,
                                                        1,
                                                        CANOPENAPP_SDO_TRANSFER_DOWNLOAD,
false);


                        break;
                    case RONIN_StartHoming:
                        IGUSD1_StartHoming(NULL);

                        break;
                }
                if (SimpleQueue_IsFull(&_t.ProcessedCommandQueue))
                    RONIN_COMMAND_PROC_DisposeCommandFromQueue(&_t.ProcessedCommandQueue);
                SimpleQueue_Insert(&_t.ProcessedCommandQueue, (int)comPtr);
            }
            break;
        case RONIN_ERROR:
            _t.State = RONIN_INITIALIZE;
            break;
    }




}

void RONIN_COMMAND_PROC_ReplyPatternOk(RONIN_COMMAND_TYPE commandType)
{
    RONIN_COMMAND *comPtr = (RONIN_COMMAND*)OSAL_Malloc(sizeof(RONIN_COMMAND));
    comPtr->ID = 0;
    comPtr->VarCount = 1;
    comPtr->Type = commandType;
    comPtr->InterfaceType = RONIN_COMM_INTERFACE_FAST;      //FIXME: ignored in
RONIN_COMMAND_PROC_GetStringToSend
    comPtr->Data[0].Integer32 = 0;

    if (SimpleQueue_IsFull(&_t.ProcessedCommandQueue))
        RONIN_COMMAND_PROC_DisposeCommandFromQueue(&_t.ProcessedCommandQueue);
    SimpleQueue_Insert(&_t.ProcessedCommandQueue, (int)comPtr);
}
```

```
void RONIN_COMMAND_PROC_ReplyHomingOk(void)
{
    RONIN_COMMAND *comPtr = (RONIN_COMMAND*)OSAL_Malloc(sizeof(RONIN_COMMAND));
    comPtr->ID = 0;
    comPtr->VarCount = 1;
    comPtr->Type = RONIN_RequestHomingComplete;
    comPtr->InterfaceType = RONIN_COMM_INTERFACE_FAST;      //FIXME: ignored in
RONIN_COMMAND_PROC_GetStringToSend
    comPtr->Data[0].Integer32 = 0;

    if (SimpleQueue_IsFull(&_t.ProcessedCommandQueue))
        RONIN_COMMAND_PROC_DisposeCommandFromQueue(&_t.ProcessedCommandQueue);
    SimpleQueue_Insert(&_t.ProcessedCommandQueue, (int)comPtr);
}

/* POTENCI?LA K??DA!
 *
 *
 * RONIN_COMMAND_PROC_DisposeCommand tiek izsaukts tikai seit. Ja neviens negribes
atbildes stringu, komanda nedisposos ies!
 *
 *
 *
 */
RONIN_COMM_INTERFACE_TYPE RONIN_COMMAND_PROC_GetStringToSend(int8_t *s)
{
    RONIN_COMMAND *comPtr = NULL;
    RONIN_COMM_INTERFACE_TYPE ret = RONIN_COMM_NO_DATA;
    if (!SimpleQueue_IsEmpty(&_t.ProcessedCommandQueue))
    {
        comPtr = (RONIN_COMMAND*)SimpleQueue_Remove(&_t.ProcessedCommandQueue);
        switch(comPtr->Type)
        {
            case RONIN_SetSpeed:
                break;
            case RONIN_SetLaserCoord:
                //sprintf(s, "WF");
                //ret = RONIN_COMM_INTERFACE_FAST;
                break;
            case RONIN_RequestRevStats:
                sprintf(s, "R;%d", _t.RPMtotal);
                ret = RONIN_COMM_INTERFACE_FAST;
                break;
            case RONIN_RequestEnergyStats:
                sprintf(s, "E;%lu", _t.Etotal);
                ret = RONIN_COMM_INTERFACE_FAST;
                break;
            case RONIN_RequestLaserStats:
                sprintf(s, "L;%lu", _t.LaserTtotal);
                ret = RONIN_COMM_INTERFACE_FAST;
                break;
            case RONIN_RequestPatternComplete:
                sprintf(s, "patternOk");
                ret = RONIN_COMM_INTERFACE_FAST;
                break;
            case RONIN_RequestPatternCompleteLaser:
                sprintf(s, "patternOkLaser");
                ret = RONIN_COMM_INTERFACE_FAST;
                break;
            case RONIN_RequestPatternCompleteMill:
                sprintf(s, "patternOkMill");
                ret = RONIN_COMM_INTERFACE_FAST;
                break;
```

```
            case RONIN_RequestHomingComplete:
                sprintf(s, "homingOk");
                ret = RONIN_COMM_INTERFACE_FAST;
                break;
            case RONIN_SetLaserPow:
                sprintf(s, "LP;%d", _t.LaserPower);
                ret = RONIN_COMM_INTERFACE_FAST;
                break;
            case RONIN_EnableMill:
                sprintf(s, "EM");
                ret = RONIN_COMM_INTERFACE_FAST;
                break;
            case RONIN_RequestLaserPow:
                sprintf(s, "LP;%d", _t.LaserPower);
                ret = RONIN_COMM_INTERFACE_FAST;
                break;
            case RONIN_RequestSpeed:
                sprintf(s, "S;%d;%d", comPtr->Data[0], comPtr->Data[1]);  //TODO: var
p?rtais?t uz pa?reiz?jiem (caur_t.(....))
                ret = RONIN_COMM_INTERFACE_FAST;
                break;
            case RONIN_RequestSystemStatus:
                sprintf(s, "SS;%d;%d", comPtr->Data[0], comPtr->Data[1]);
                ret = RONIN_COMM_INTERFACE_FAST;
                break;
            case RONIN_RequestBattVoltage:
                sprintf(s, "V;%d", comPtr->Data[0]);
                ret = RONIN_COMM_INTERFACE_FAST;
                break;
            case RONIN_RequestMotorCurrents:
                sprintf(s, "I;%d;%d;%d;%d",
                                    comPtr->Data[0], comPtr->Data[1],
                                    comPtr->Data[2], comPtr->Data[3]);
                ret = RONIN_COMM_INTERFACE_FAST;
                break;
            case RONIN_SetMotorControlMode:


                break;
        }
        RONIN_COMMAND_PROC_DisposeCommand(comPtr);
    }
    return ret;
                                                    }
```

Fails "RoninCommandProc.h"

```
/*
 * File:   RONINCommandProc.h
 * Author: Vitalijs
 *
 * Created on otrdiena, 2019, 11 j?nijs, 17:01
 */

#ifndef RONINCOMMANDPROC_H
#define     RONINCOMMANDPROC_H

#ifdef      __cplusplus
extern "C" {
#endif

#include <stdint.h>
#include <string.h>
#include <stddef.h>
#include <errno.h>
#include "simple_queue.h"
#include "system_definitions.h"
#include "system_config.h"
#include "osal/osal.h"
#include "CANopenApp.h"


///Max command data size in words
#define RONIN_COMMAND_DATA_VAR_COUNT_MAX 8


/*
 * General command structure
 * <command id>;<command ascii name>;[parameter1;parameter2...]
 *
 * ---------RONIN_SetSpeed--------------
 * <command id>;SSP;<left speed>;<right speed>
 * 1;SSP;123;123            set left and right speed in RPM [-250...250]
 *                          negative values - backward direction
 *
 * ---------RONIN_SetLaserCoord---------
 * <command id>;SLC;<x>;<y>;<z>
 * 1;SLC;100;100;100        set laser CNC coordinates in mm [0...axis Max]
 *
 * reply: "patternOkLaser"
 *
 * ---------RONIN_SetMillCoord----------
 * <command id>;SMC;<x>;<y>;<z>
 * 1;SMC;100;100;100        set mill CNC coordinates in mm [0...axis Max]
 *
 * reply: "patternOkMill"
 *
 * ---------RONIN_SetLaserPow-----------
 * <command id>;SL;<power>
 * 1;SL;50                  set laser power in % [0...100]
 *
 * ---------RONIN_EnableLaser-----------
 * <command id>;EL;<state>
 * 1;EL;1                     enable laser (if 1) [0;1]
 *
 * ---------RONIN_EnableMill-----------
 * <command id>;EM;<duration>
 * 1;EM;100                    enable mill for duration (ms), resolution 100 ms
 *                           if 0, mill is disabled
```

```
 *
 * ---------RONIN_DrawPattern----------
 * <command id>;DPA;<type>;<x>;<y>;<z>;<w>;<h>
 * 1;DPA;1;100;100;100;20;20
 *
 *  Draw pattern type with laser ON at point x, y, with size w, h and at constant height z
 *  x,y -> x+w,y
 *  x+w -> x+w,y+h
 *  x+w,y+h -> x,y+h
 *  x,y+h -> x,y
 *  type:
 *      - 1 - rectangle
 *      - 2 - horizontal lines (along x axis) with step 3 mm
 *
 *  reply: "patternOkLaser"
 *
 * --------RONIN_SetMotorControlMode-----
 * <command id>;SMM;<modeType>
 * 1;SMM;0
 *  modeType:
 *      - 0 - feedback with current and speed sensors
 *      - 1 - raw PWM
 */

typedef enum
{
    RONIN_SetSpeed = 1,
    RONIN_SetLaserCoord,
    RONIN_SetMillCoord,
    RONIN_DrawPattern,
    RONIN_RequestRevStats,
    RONIN_RequestEnergyStats,
    RONIN_RequestLaserStats,
    RONIN_RequestPatternComplete,
    RONIN_RequestHomingComplete,
    RONIN_SetLaserPow,
    RONIN_EnableLaser,
    RONIN_EnableMill,
    RONIN_RequestLaserPow,
    RONIN_RequestSpeed,
    RONIN_RequestSystemStatus,
    RONIN_RequestBattVoltage,
    RONIN_RequestMotorCurrents,
    RONIN_SetMotorControlMode,
    RONIN_CNC_Ax1,
    RONIN_ReadCANObj,
    RONIN_WriteCANObj,
    RONIN_StartHoming,
    RONIN_RequestPatternCompleteLaser,
    RONIN_RequestPatternCompleteMill
} RONIN_COMMAND_TYPE;

#define RONIN_COMMAND_ASCII_STRINGS     "SSP",  \
                                        "SLC",  \
                                        "SMC",  \
                                        "DPA",  \
                                        "RRS",    \
                                        "RES",    \
                                        "RLS",    \
                                        "RPC",  \
                                        "RHC", \
                                        "SL",  \
                                        "EL",   \
                                        "EM",   \
```

```
                                        "LPR", \
                                        "RSP",  \
                                        "RST",  \
                                        "RBV",  \
                                        "RMC",  \
                                        "SMM",  \
                                        "Ax1",   \
                                        "CO",    \
                                        "WCO",  \
                                        "HO"
typedef enum
{
    RONIN_COMM_NO_DATA = 0,
    RONIN_COMM_INTERFACE_FAST = 1,
    RONIN_COMM_INTERFACE_RELIABLE = 2
} RONIN_COMM_INTERFACE_TYPE;

typedef enum
{
    RONIN_INITIALIZE = 0,
    RONIN_INIT_BUSY,
    RONIN_TASKS,
    RONIN_ERROR,
} RONIN_STATE;

typedef union
{
    int32_t Integer32;
    uint32_t Unsigned32;
    float Floating32;
} genericData32_t;

typedef struct
{
    int32_t ID;
    RONIN_COMMAND_TYPE Type;
    genericData32_t Data[RONIN_COMMAND_DATA_VAR_COUNT_MAX];
    ///Token count
    int32_t VarCount;
    RONIN_COMM_INTERFACE_TYPE InterfaceType;
} _RONIN_COMMAND;

typedef _RONIN_COMMAND RONIN_COMMAND;




void RONIN_COMMAND_PROC_Initialize(void);
void RONIN_COMMAND_PROC_ParseString(int8_t *str);
bool RONIN_COMMAND_PROC_GetCommand(RONIN_COMMAND *ptr);
void RONIN_COMMAND_PROC_DisposeCommand(RONIN_COMMAND *comPtr);
void RONIN_COMMAND_PROC_WDT_Timeout(void);

void RONIN_COMMAND_PROC_ReplyPatternOk(RONIN_COMMAND_TYPE commandType);
void RONIN_COMMAND_PROC_Tasks(void);
RONIN_COMM_INTERFACE_TYPE RONIN_COMMAND_PROC_GetStringToSend(int8_t *s);
void RONIN_COMMAND_PROC_DisposeCommandFromQueue(SIMPLE_QUEUE *q);

#ifdef      __cplusplus
}
#endif

#endif      /* RONINCOMMANDPROC_H */
```

Fails "Ronin_laser.c"

```
#include "RONIN_laser.h"

typedef enum
{
    LASER_STATE_UNINITIALIZED,
    LASER_STATE_OPERATING
} RONIN_LASER_STATE;

typedef struct
{
    RONIN_LASER_STATE State;
    DRV_HANDLE TimerHadle;
    DRV_HANDLE OCHadle;
    int16_t Power;
    struct
    {
        int32_t LaserEnabled:1;
        int32_t LaserEnabledSoft:1;
    } Flags;
} RONIN_LASER_DATA;

RONIN_LASER_DATA _tl;

void RONIN_LASER_Initialize(void)
{
    _tl.State = LASER_STATE_UNINITIALIZED;
    _tl.TimerHadle = DRV_HANDLE_INVALID;
    _tl.OCHadle = DRV_HANDLE_INVALID;
    _tl.Flags.LaserEnabled = 0;
    _tl.Flags.LaserEnabledSoft = 0;
}

void RONIN_LASER_AddPointPair(RONIN_LASER_POINTPAIR *pp)
{

}

void RONIN_LASER_AddPointPairRange(RONIN_LASER_POINTPAIR *pp, uint32_t count)
{

}

void RONIN_LASER_StartSequence(void)
{

}

bool RONIN_LASER_IsSequenceComplete(void)
{
    return true;
}

/*
 * Power - 0...100%
 */
void RONIN_LASER_SetPower(uint16_t power)
{
    if (power <= 100)
        _tl.Power = power * LAER_POWER_MULT;
}

void RONIN_LASER_Enable(void)
```

```
{
    _tl.Flags.LaserEnabled = 1;
}

void RONIN_LASER_Disable(void)
{
    _tl.Flags.LaserEnabled = 0;
}


void RONIN_LASER_Tasks(void)
{
    switch(_tl.State)
    {
        case LASER_STATE_UNINITIALIZED:
            //Opening timer driver
            if (_tl.TimerHadle == DRV_HANDLE_INVALID)
                _tl.TimerHadle = DRV_TMR_Open(DRV_TMR_INDEX_1,
                    DRV_IO_INTENT_READWRITE | DRV_IO_INTENT_EXCLUSIVE);
            if (_tl.TimerHadle == DRV_HANDLE_INVALID)
                break;
            //Opening OC driver
            if (_tl.OCHadle == DRV_HANDLE_INVALID)
                _tl.OCHadle = DRV_OC_Open(DRV_OC_INDEX_0,
                        DRV_IO_INTENT_READWRITE | DRV_IO_INTENT_EXCLUSIVE);
            if (_tl.OCHadle == DRV_HANDLE_INVALID)
                break;


            DRV_TMR_AlarmRegister(_tl.TimerHadle, LASER_PWM_PERIOD, true, 0, NULL);
            DRV_TMR_Start(_tl.TimerHadle);
            DRV_OC_PulseWidthSet(_tl.OCHadle, LASER_ZERO_POWER);
            DRV_OC_Start(DRV_OC_INDEX_0,
                        DRV_IO_INTENT_READWRITE | DRV_IO_INTENT_EXCLUSIVE);
            _tl.State = LASER_STATE_OPERATING;
            break;
        case LASER_STATE_OPERATING:
            if (_tl.Flags.LaserEnabled || _tl.Flags.LaserEnabledSoft)
            {
                DRV_OC_PulseWidthSet(_tl.OCHadle, _tl.Power);
                BSP_LEDOn(BSP_LED_1);
                BSP_LEDOn(BSP_LED_2);
                BSP_LEDOn(BSP_LED_3);
            }
            else
            {
                DRV_OC_PulseWidthSet(_tl.OCHadle, LASER_ZERO_POWER);
                BSP_LEDOff(BSP_LED_1);
                BSP_LEDOff(BSP_LED_2);
                BSP_LEDOff(BSP_LED_3);
            }
            break;
    }
}
```

Fails “Ronin_laser.h”

```
/*
 * File:   RONIN_laser.h
 * Author: Vitalijs
 *
 * Created on tre?diena, 2019, 12 j?nijs, 13:38
 */

#ifndef RONIN_LASER_H
#define     RONIN_LASER_H

#ifdef      __cplusplus
extern "C" {
#endif

#include <stdint.h>
#include <stdbool.h>
#include "system_config.h"
#include "system_definitions.h"

#define LASER_PWM_PERIOD    200
#define LAER_POWER_MULT 2
#define LASER_ZERO_POWER 0
#define LASER_MAX_POWER LAER_POWER_MULT * 100

typedef struct
{
    int32_t X;
    int32_t Y;
} RONIN_LASER_POINTPAIR;

void RONIN_LASER_Initialize(void);
void RONIN_LASER_AddPointPair(RONIN_LASER_POINTPAIR *pp);
void RONIN_LASER_AddPointPairRange(RONIN_LASER_POINTPAIR *pp, uint32_t count);
void RONIN_LASER_StartSequence(void);
bool RONIN_LASER_IsSequenceComplete(void);
void RONIN_LASER_Tasks(void);

void RONIN_LASER_SetPower(uint16_t power);
void RONIN_LASER_Enable(void);
void RONIN_LASER_Disable(void);

#ifdef      __cplusplus
}
#endif

#endif      /* RONIN_LASER_H */
```

Fails “Ronin_mill.c”

```
#include "RONIN_mill.h"

typedef enum
{
    MILL_STATE_UNINITIALIZED,
    MILL_STATE_OPERATING
} RONIN_MILL_STATE;

typedef struct
{
    RONIN_MILL_STATE State;
    SYS_TMR_HANDLE Tmr100msHandle;
    uint32_t TimeCounter;
    int16_t Power;
    struct
    {
        int32_t InitiateMill:1;
        int32_t MillEnabled:1;
        int32_t MillEnabledSoft:1;
    } Flags;
} RONIN_MILL_DATA;

RONIN_MILL_DATA _tm;

void RONINMill_Tmr100ms_Callback ( uintptr_t context, uint32_t currTick );

void RONINMill_Tmr100ms_Callback ( uintptr_t context, uint32_t currTick )
{
    if (_tm.Flags.InitiateMill)
    {
        _tm.Flags.InitiateMill = 0;
        _tm.Flags.MillEnabled = 1;
    }
    if (_tm.TimeCounter)
        _tm.TimeCounter--;
    else
        _tm.Flags.MillEnabled = 0;
}

void RONIN_MILL_Initialize(void)
{
    _tm.State = MILL_STATE_UNINITIALIZED;
    _tm.Flags.MillEnabled = 0;
    _tm.Flags.MillEnabledSoft = 0;
    _tm.Tmr100msHandle = DRV_HANDLE_INVALID;
    _tm.TimeCounter = 0;
}

void RONIN_MILL_Enable(uint32_t ms)
{
    _tm.Flags.InitiateMill = 1;
    _tm.TimeCounter = ms / 100;
}

void RONIN_MILL_Disable(void)
{
    _tm.Flags.MillEnabled = 0;
}


void RONIN_MILL_Tasks(void)
{
```

```
    switch(_tm.State)
    {
        case MILL_STATE_UNINITIALIZED:
            if (SYS_TMR_Status(sysObj.sysTmr) == SYS_STATUS_READY)
            {
                if (_tm.Tmr100msHandle == DRV_HANDLE_INVALID)
                    _tm.Tmr100msHandle = SYS_TMR_CallbackPeriodic(100, 0,
&RONINMill_Tmr100ms_Callback);
                if (_tm.Tmr100msHandle != DRV_HANDLE_INVALID)
                    _tm.State = MILL_STATE_OPERATING;
            }
            break;
        case MILL_STATE_OPERATING:
            if (_tm.Flags.MillEnabled || _tm.Flags.MillEnabledSoft)
            {
                MillControlOn();
            }
            else
            {
                MillControlOff();
            }
            break;
    }
}
```

Fails “Ronin_mill.h”

```
/*
 * File:   RONIN_laser.h
 * Author: Vitalijs
 *
 * Created on tre?diena, 2019, 12 j?nijs, 13:38
 */

#ifndef RONIN_MILL_H
#define     RONIN_MILL_H

#ifdef      __cplusplus
extern "C" {
#endif

#include <stdint.h>
#include <stdbool.h>
#include "system_config.h"
#include "system_definitions.h"



void RONIN_MILL_Initialize(void);

void RONIN_MILL_Tasks(void);

void RONIN_MILL_Enable(uint32_t ms);
void RONIN_MILL_Disable(void);

#ifdef      __cplusplus
}
#endif

#endif      /* RONIN_MILL_H */
```

Fails "Ronin_motor.c"

```
#include "RONIN_motor.h"

static RONIN_MOTOR_DATA _tmd;


void MotorTimer_Callback ( uintptr_t context, uint32_t currTick )
{

}

void MotorTimer100_Callback ( uintptr_t context, uint32_t currTick )
{
    //SYS_CONSOLE_PRINT("Motor actual velocity: %d \r\n", CO_OD_RAM.motorActualVelocity1);
}

void RONIN_MOTOR_Initialize(void)
{
    memset(&_tmd, 0, sizeof (_tmd));
    _tmd.MotorControlMode = 0;
    _tmd.State = RONIN_MOTOR_STATE_INIT;
}

void RONIN_MOTOR_Tasks(void)
{
    switch (_tmd.State)
    {
        case RONIN_MOTOR_STATE_INIT:
            if (SYS_TMR_Status(sysObj.sysTmr) == SYS_STATUS_READY)
            {
                _tmd.Tmr10msHandle = SYS_TMR_CallbackPeriodic(10, 0,
&MotorTimer_Callback);
                _tmd.Tmr100msHandle = SYS_TMR_CallbackPeriodic(100, 0,
&MotorTimer100_Callback);
            }
            else
                break;
            _tmd.State = RONIN_MOTOR_STATE_TASKS;
            break;
        case RONIN_MOTOR_STATE_TASKS:
            break;
    }
}

void RONIN_MOTOR_SetSpeed(RONIN_MOTOR_ID motor, int16_t speed)
{
    int32_t spd = speed;
    //if PWM mode, scale up to PWM max
//    if (_tmd.MotorControlMode == 1)
//    {
//        speed *= 32;        //250 * 32 = 8000;
//    }
    switch (motor)
    {
        case RONIN_MOTOR_FL:
            CO_OD_RAM.motorTargetVelocity1 = speed;
            break;
        case RONIN_MOTOR_RL:
            CO_OD_RAM.motorTargetVelocity2 = speed;
            break;
        case RONIN_MOTOR_RR:
            CO_OD_RAM.motorTargetVelocity3 = speed;
            break;
```

```c
        case RONIN_MOTOR_FR:
            CO_OD_RAM.motorTargetVelocity4 = speed;
            break;
    }


}

void RONIN_MOTOR_SetControlMode(int16_t mode)
{
    _tmd.MotorControlMode = mode;
    if (mode)
    {
        CO_OD_RAM.motorControlword1 |= 4;
        CO_OD_RAM.motorControlword2 |= 4;
        CO_OD_RAM.motorControlword3 |= 4;
        CO_OD_RAM.motorControlword4 |= 4;
    }
    else
    {
        CO_OD_RAM.motorControlword1 &= ~4;
        CO_OD_RAM.motorControlword2 &= ~4;
        CO_OD_RAM.motorControlword3 &= ~4;
        CO_OD_RAM.motorControlword4 &= ~4;
    }
}
```

Fails “Ronin_motor.h”

```
/*
 * File:   RONIN_CNC.h
 * Author: Vitalijs
 *
 * Created on tre?diena, 2020, 12 augusts, 08:45
 */

#ifndef RONIN_CNC_H
#define     RONIN_CNC_H

#ifdef      __cplusplus
extern "C" {
#endif

#include <stdint.h>
#include <stdbool.h>
#include "system_config.h"
#include "system_definitions.h"

void RONINCNC_Initialize(void);
void RONINCNC_Tasks(void);

void RONINCNC_SetLaserPos(int32_t x, int32_t y, int32_t z);
void RONINCNC_SetMillPos(int32_t x, int32_t y, int32_t z);
void RONINCNC_DrawLaserPattern1(int32_t x, int32_t y, int32_t z, int32_t w, int32_t h);
void RONINCNC_DrawLaserPattern2(int32_t x, int32_t y, int32_t z, int32_t w, int32_t h);

#ifdef      __cplusplus
}
#endif

#endif      /* RONIN_CNC_H */
```

Fails "simple_queue_config.h"

```
/*
 * File:   queue_config.h
 * Author: Vitalijs
 *
 * Created on otrdiena, 2019, 4 j?nijs, 16:40
 */

#ifndef SIMPLE_QUEUE_CONFIG_H
#define     SIMPLE_QUEUE_CONFIG_H

#ifdef      __cplusplus
extern "C" {
#endif

#define SIMPLE_QUEUE_MAX 64


#ifdef      __cplusplus
}
#endif

#endif      /* QUEUE_CONFIG_H */
```