University of Maribor
Faculty of Agriculture and Life Sciences
Biosystems Engineering

FRE2023

Maribor - SLOVENIA, 12. - 15. June

20th anniversary

www.fieldrobot.com/event

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International Field Robot Event

FIELD ROBOT EVENT 2023 - BOOKLET
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University of Maribor, Faculty of Agriculture and Life Sciences, Slovenia
Damijan Kelc, Denis Stajnko, Erik Rihter, Jurij Rakun, Marinko Grbić, Matjaž Sagadin, Miran Lakota, Peter Berk, Peter Bernad and Peter Vindiš.

Students: Gašper Majal, Kaja Žučko, Katarina Lipovšek, Marjan Dreier, Miha Mahor, Timotej Plankar, Peter Orešnik

SPONSORS

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University of Maribor
Faculty of Agriculture and Life Sciences

International Field Robot Event

Field Robot Event 2023

Welcome to the 20th Field Robot Event

This year, the Field Robot Event (FRE) will take place from 13^{th} to 15^{th} of June 2023 at the University of Maribor in Slovenia, specifically at the Faculty of Agriculture and Life Sciences. Teams from all over Europe will once again meet and compete with their small autonomous field robots to prove that they are the best.

This will be the 20^{th} FRE and a special occasion to reflect on the work done over the last 20 years. It will show to the spectators that FRE is much more than just a competition. It is a breeding ground for new ideas and solutions that will fundamentally change the traditional way of farming.

What is FRE?

FRE is an annual competition in which international student teams from Europe and the world compete with their field robots to find the best solutions to agricultural mechanisation problems. The competition was initiated in 2003 and has since established itself as a permanent fixture in agricultural robotics. The aim of the competition is to test future-oriented technologies in the field of robotics and precision farming in real field conditions, and to give young scientists the opportunity to exchange ideas in an international circle of participants, to form networks and to further develop their ideas. Tasks in the field of navigation and application have to be solved in an experimental field with maize plants.

This year the FRE will focus on the following tasks:

- **Navigation** – show that robots can move autonomously through the field and know precisely where they are and what to do next
- **Treatment of plants** – to prove that smart robotic systems can precisely detect and treat plants where needed, saving a huge portion of input resources
- **Sensing** – demonstrate that AI driven solutions will help the robots to distinguish the objects in sight without the need of human intervention
- **Obstacle avoidance** – improve the safety mechanisms of agricultural machines in order to prevent injuries of human beings and help protect wild life

FRE2023 TASK DESCRIPTION

Task1: navigation

General description

For this task, the robots are navigating autonomously through a real maize field. Turning must follow adjacent rows for track 1 to 5. From exiting track 5 the robot must follow a given particular turning pattern. This task is all about accuracy, smoothness, and speed of the navigation operation between the rows. Within three minutes the robot navigates between the rows. The aim is to cover as much travelled distance as possible. You find an example field and driving pattern in Figure 1.1.

The first 3 tracks are without intra-row gaps to make it easy for robots to start. The rest of the field – track 4 to 11 – there are intra-row gaps even sometimes on both sides. In the last part – after track 5 – the robot has to follow a particular given turning and row pattern. The pattern may look as:

S – 1L – 1R – 3L – 2L – 2R – F.

Random stones and pebbles are placed along the path. Therefore, machine ground clearance is required. In order to make it easier for sensors there will be no gaps at the row entries and exits. The ends or beginnings of the rows may not be in the same line. The headland will be perhaps indicated by a fence or ditch or similar.

Rules for robots

Each robot must start after a starting indication (acoustic signal) within 1 min. The maximum available time for the run is 3 min.

Points distribution

The distance travelled following the given path during task duration is measured. (As soon as the robot leaves the specified path, the distance measurement will stop.) The final distance will be calculated including especially a bonus factor when the end of the field is reached in less time than 3 min. The final distance including a bonus factor is calculated as:

S_{final} [m] = $S_{corrected}$ [m] * 3 [min] / $t_{measured}$ [min]

The corrected distance includes travelled distance and the penalty values. Travelled distance, penalty values and performance time are measured by the jury officials.
Crop plant damage by the robot will result in a penalty of 2% of total row length distance in meter per damaged plant. (Example: 10 rows x 10 m = 100 m max. distance, means a penalty of 2 m per damaged plant.)

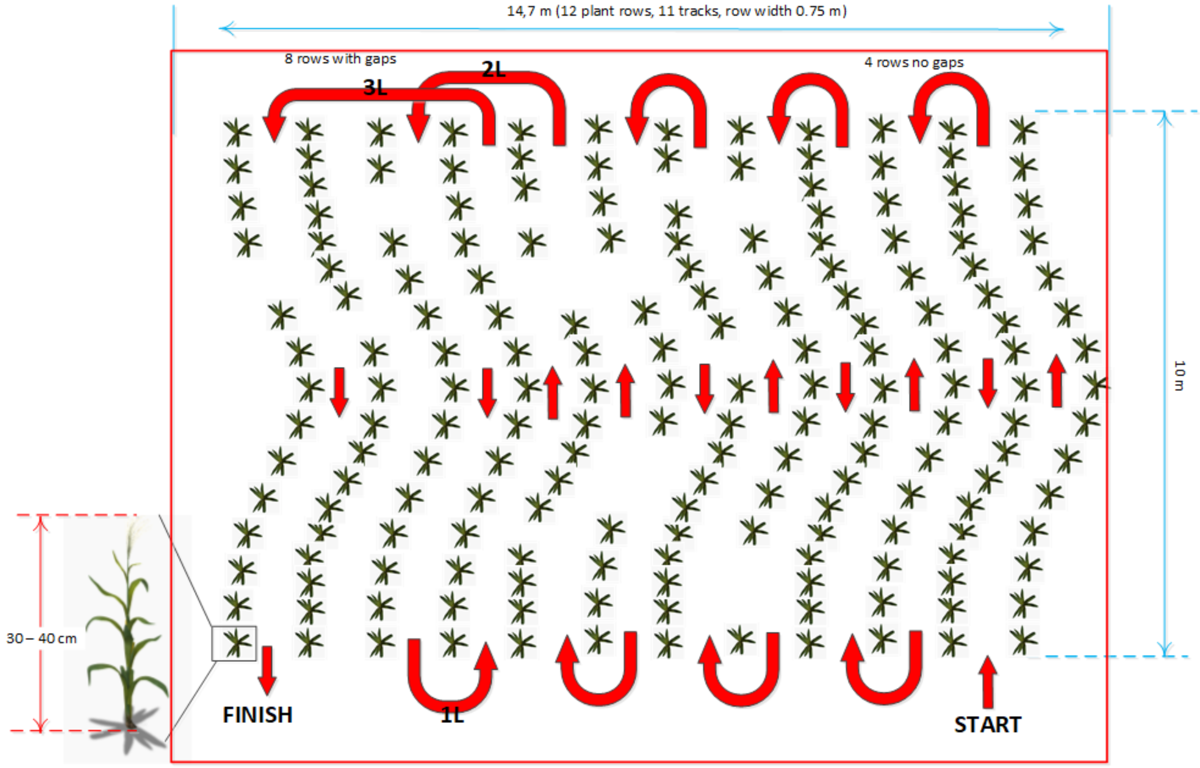


Figure 0.1: Concept of field structure for navigation task (example); Track 1 to 3 with no gaps, track 4 to 11 with gaps. After track 7 on navigation with pattern 2L (second left), 1L (one left) and 3L (third left) as an example. The headlands are 2 m wide.

Task2: treating (spraying) the plants

General description

For this task, the robots are navigating autonomously through a real maize field, like in first part of task 1, but skipping every second row. In addition to this, the robots must treat the plants when the plants are present and stop the treatment, where the plants are not present.

In optimal conditions, the robots should start spraying the plants on their left and right side. If plants are missing on one side, the robot should stop spraying on that side until it does not detect new plants on that side. In addition, the robot should stop spraying when it reaches the end of the row and starts the turning procedure. In real world, the robots might run out of water or might not even have the capabilities to spray. Therefore, the robots must be equipped with two indicators / bright lights, turning on and off in accordance to the presence of plants.
For the contest, the spraying medium will be water.

Rules for robots

Each robot must start after a starting indication (acoustic signal) within 1 min. The maximum available time for the run is 3 min.

Points distribution

There will be 10 areas in the field where the plants will be missing approx. 1 m long empty rows, distributed on one or possibly both sides. So, in total, 10 m of plants will be missing. The points will be awarded according to the number of successfully detected empty regions ($S_{missing}$), with a weight set to 1, and the total distance travelled ($S_{travelled}$).

S_{final} [m] = 10 * weight * $S_{missing}$ [m] * + $S_{travelled}$ [m]

A bonus factor will be awarded to the robots, that will actually spray the plants. To evaluate this, water sensitive paper (WSP) will be placed on dry wooden planks and these wooden planks will be placed on the ground where the plants are missing[1]. The WSPs will be positioned one in every 10 cm and based on the number of wet WSPs the weight will be set as follows:

The percentage of all WSP that are dry[2]	Weight
80% or more	2
60% to 79%	1.75
40% to 59%	1.5
Less than 40%	1.25
0 %, correct indication	1
0 %, false indication	0

where, if needed, the percentage will be rounded to the first integer value.

Crop plant damage by the robot will result in a penalty of 2% of total row length distance in meter per damaged plant. (Example: 10 rows x 10 m = 100 m max. distance, means a penalty of 2 m per damaged plant.)

In case the robot fails to detect the plants in the middle of row where the plants are not missing, evident as the robot will stop spraying and / or the light indicator will turn off, this will result in penalty points as in the case of damaged plants (e. g. one damaged plant per one false positive action)[3].

Task3: sensing and recognizing possible obstacles

General description

To be successful in the next task, the robots will be tested and evaluated how good they are in recognizing new possible obstacles. Therefore, set of images (one after another) will be placed in

[1] The wood plank with WPS will be positioned close to the last plant. If this first WSP will be wet, the weights will be applied. If the robot indicates the area with missing plants, but fails to spray (as it probably ran out of water) and the WSPs are all dry, the weight will be set to 1.

[2] Pay attention to drift from the previous rows as it might ruin the results.

[3] Some robots might be quite accurate to detect where the plants are and where there are just (small portions) of leaves present. This might result in constant on / off spraying situation in areas where the plants are present. In order to avoid penalty points, the teams are advised to keep spraying / indicator on until the next plant (if present).

front of the robot, each of them from one of the three groups: a deer, a human and something else. The robots must have an acoustic and / or visual indicator that will let the jury / audience know what the robot sees: a human, a deer or unknown.

To make the competition as fare as possible, each of the teams will provide 3 images before the start of the tasks. A random selection will then be made where one of these 3 images will be used in the final set (so if they are 15 teams competing, the set will consist of 15 images). All images will then be printed (each) on a white A3 sheet of paper and place in random order in front of the robot at a distance of 1.5 m. The robots then have a 5 sec time frame to make a detection, recognize it and indicate what they see.

For this task, the robots will be place in the beginning of the field between the two plant rows, but will not move / drive during this task. Instead, the robots will focus on what is placed in front of them and make a classification. Only one classification per obstacle can be made and cannot be changed (only the first counts).

Rules for robots

Each robot must start the detection after a starting indication (acoustic signal) within 1 min. The maximum available time for sensing is 5 seconds per obstacle. There can be up to 10 seconds long window to change the pictures by the jury (by first removing the previous picture and placing the new). Once a detection is made, it cannot change in next 5 seconds. Only the first detection counts.

Points distribution

The jury assesses the detection and classification during the run:

Detected object and right category (true positive)	5 points
Detected object wrong category (false positive)	-5 points

Task4: static and dynamic obstacles

General description

This task is all about safety. The robots will drive through the field as in task 1, but without skipping the rows. In addition, they will have to detect static and dynamic obstacles that might / will come in its path. If the obstacle is dynamic, the robot will stop and make an acoustic sound and / or visual indication (eg. bright flashes) and the obstacle will move in 5 seconds, which means that the robot can continue the driving. If the obstacle is static, it will not move, and the robot must drive back and continue in to the next row.

As in task 3, the robots might encounter an obstacle, but now while driving. For this task there will be 5 obstacles on the field; 3 of them dynamic, and 2 of them static. For dynamic obstacles, a picture of a human will be placed and removed once a clear indicator (audio or visual sign) will be given by the robot. If no indication will be made, the obstacle will remain in its path and the robot will have to move backwards and continue into the next row and this will count as a false positive. For static obstacles, an image of a deer will be placed on the path of the robot and will not be removed, where the robot must give a clear indication what it recognized. If the robot gives a wrong indication it will count as a false positive.

In contrast to the previous task, the pictures of the obstacles will be provided to the teams before the event.

Crop plant damage by the robot will result in a penalty of 2% of total row length distance in meter per damaged plant. (Example: 10 rows x 10 m = 100 m max. distance, means a penalty of 2 m per damaged plant.)

Rules for robots

Each robot must start after a starting indication (acoustic signal) within 1 min. The maximum available time is 5 min.

Points distribution

The jury assesses the detection and classification during the run:

Path travelled	x*0.5 points
Successful detection of a static / dynamic obstacle (true positive)	10 points
Unsuccessful detection of a static / dynamic obstacle (false positive)	-10 points

Task5: Freestyle

Description

Teams are invited to let their real robot perform freestyle on the event venue. The explanation as well as the performance must be shown to the jury and the spectators. The team must explain the idea and the machine. Comments during the robot's performance are also welcome.
Creativity and fun are required for this task as well as an application-oriented performance. The freestyle task should be related to an agricultural application. Teams will have a time limit of five minutes for the presentation including the robot's performance.

Points distribution

The jury will assess by points P the

- P1 : agronomic idea (originality)

- P2 : technical complexity
- P3 : robot performance

Points P will be given from 0 (insufficient) to 10 (excellent) for each criterion (P1, P2 and P3). The total points will be calculated using the following formula:
final points = P1 + P2 + P3

End results

The teams will collect their points by combining the results of first 4 tasks. For each of the tasks the team can get up to 25% of the points for the overall assessment and the percentage for each of the task will calculated based on the point they won divided by points won by the winning team of that task. To avoid possible negative points, all points will be subtracted by the lowest points achieved in that task. So, the final scores will be calculated as follows:

$$Overall_{points}(x) = \sum_{n=1}^{4} \frac{points(n,x) - \min\,(task(n))}{4 * \ (\max\big(task(n)\big) - \ \min\,(task(n)))}$$

where x is the number of the team, points(n,x) represent the points for team x in task n, and task(n) and a vector of all the points for that specific task (n).

University of Maribor
Faculty of Agriculture and Life Sciences

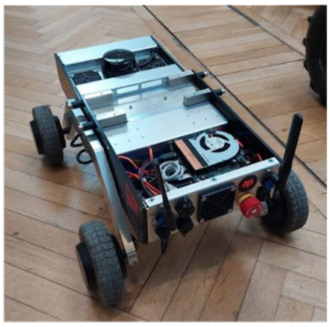
International Field Robot Event

Acorn – University of Applied Sciences Osnabrück / University of Osnabrück

Team Name	Team acorn
Names of team members:	Christopher Sieh (TC), Arthur Schreiber, Leon Rabius, Justus Braun, Phillip Gehricke, Andreas Klaas, Jannik Jose, Can-Leon Petermöller, Simon Balzer, Lena Brüggemann (TC), Lara Lüking
Team captain's name:	Lena Brüggemann, Christopher Sieh
Instructor(s):	Alexander Mock (UOS), Andreas Linz (HSOS), Isaak Ihorst (UOS)
Institution:	University Osnabrück, University of Applied Sciences Osnabrück
Department:	University: Computer Science, University of Applied Sciences: Faculty of Engineering.
Country:	Germany
Street / Number:	Albrechtstr. 30 49076 Osnabrück / Neuer Graben 29 49074 Osnabrück
ZIP Code / City	Osnabrück
Email:	a.linz@hs-osnabrueck.de - amock@uni-osnabrueck.de
Webpage:	

INFORMATION ABOUT THE ROBOT			
W x L x H (cm):		Weight (kg):	
Commercial or prototype:	prototype	Total no. of wheels / no. driven wheels:	4 of 4 driven
Drivetrain concept / max. speed (m/s):	Differential Drive	Turning radius (cm):	0
0Battery type / capacity (Ah):	2x 36V/6Ah	Total motor power (W):	4x 100W
No. of sensors internal / external: Sensor type:	6 int, 5 ext Wheel rotation sensors, IMU, 3D-Sensor, 2D-Sensors, Cameras		

Controller system software description (sensor data analysis, machine control etc.)
The sensors publish their data over ethernet or USB to a Jetson which computes the behaviour of the robot. The whole system is based around ROS noetic, running on Ubuntu 20.04. The recognition of the images is done by a neuronal network on a Jetson. The used data comes from the cameras and 3D scanners. 3D point clouds are processed with an algorithm to detect rows and plan a safe path.
Controller system hardware description (motor controller, computer etc.)
The robot has 4 wheels, each driven by a BLDC-motor. With the differential drive the turning radius is turned to a minimum. The only computer is a Jetson. It solves object detection with real-sense cameras and evaluates the 3D and 2D scanner data to a safe navigation path.
Short strategy description for navigation and applications
The robot detects maize rows in a point cloud, applying all known information from the rules and outputs a path inside and outside the field.
These are the commercial team sponsors & partners (if there are)
AMAZONEN-WERKE H. DREYER SE & Co. KG., iotec GmbH



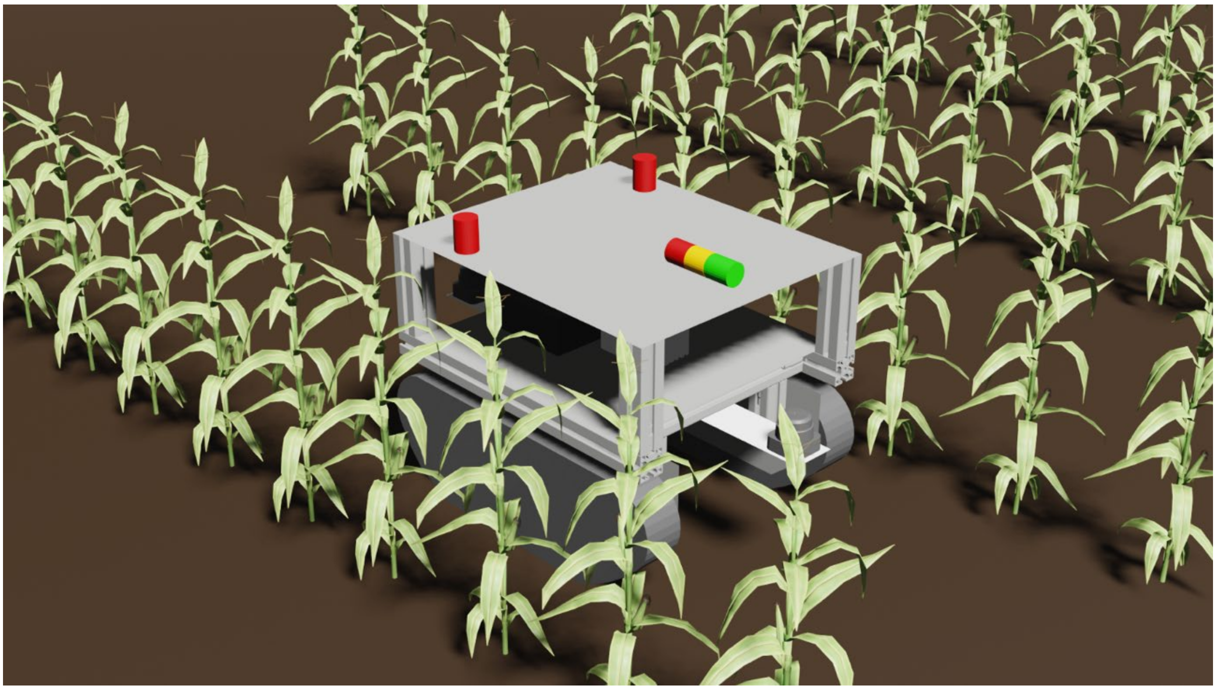
AIRLab Polimi / Grasslammer

Team Name	AIRLab Polimi
Names of team members:	Simone Mentasti, Paolo Cudrano, Mirko Usuelli, Matteo Zinzani, Alba Lo Grasso, Carlo Arnone, Andrea Cerutti, Abdelrahman Tarek Farag
Team captain's name:	Simone Mentasti
Instructor(s):	Prof. Matteo Matteucci
Institution:	Politecnico di Milano
Department:	Dipartimento di Elettronica, Informazione e Bioingegneria
Country:	Italy
Street / Number:	Via Giuseppe Ponzio, 34/5
ZIP Code / City	20133 Milano MI
Email:	simone.mentasti@polimi.it, paolo.cudrano@polimi.it, mirko.usuelli@polimi.it, matteo.matteucci@polimi.it
Webpage:	https://www.deib.polimi.it/eng/home-page

INFORMATION ABOUT THE ROBOT			
W x L x H (cm):	43.00 x 58.50 x 42.00	Weight (kg):	15
Commercial or prototype:	Prototype	Total no. of wheels / no. driven wheels:	4

Drivetrain concept / max. speed (m/s):	1	Turning radius (cm):	0
Battery type / capacity (Ah):	12	Total motor power (W):	150
No. of sensors internal / external: Sensor type:	4x Motor encoders 1x LiDAR 1x Laserscan 2x Cameras		

Controller system software description (sensor data analysis, machine control etc.)
One camera tracks within the vegetation, while the other camera detects objects. Along with laserscans and LiDAR, these sensors provide a complete understanding of the robot's surroundings. This comprehensive perception system helps the robot make informed decisions and take appropriate actions.
Controller system hardware description (motor controller, computer etc.)
The robot uses custom embedded electronics developed by Nova Labs, which communicate with ROS through microROS.
Short strategy description for navigation and applications
The row navigation strategy involves real-time clustering estimation of plants to determine the next pose to follow, while simultaneously creating a map of the crop field. AI-based models are employed to handle detection tasks in conjunction with navigation.
These are the commercial team sponsors & partners (if there are)
Nova Labs, Claas Foundation



Amazeing / Precision Farming Operations with Lidar (PF-OWL)

Team Name	Amazeing
Names of team members:	Luis Schnepel, Henrik Henning, Torben Schwiedernoch, Dennis Hoffmann, Tobias Goda
Team captain's name:	Tobias Goda
Instructor(s):	Prof. Dr. Burkhard Wrenger
Institution:	Technische Hochschule Ostwestfalen-Lippe
Department:	Autonomous Sensor Systems, Faculty 8, Precision Farming
Country:	Germany
Street / Number:	An der Wilhelmshöhe 44
ZIP Code / City	37671 Höxter
Email:	Burkhard.wrenger@th-owl.de
Webpage:	https://github.com/buwrenger/THOWL_FRE2023

INFORMATION ABOUT THE ROBOT			
W x L x H (cm):	50x70x35	Weight (kg):	15KG, 20KG with Water
Commercial or prototype:	prototype	Total no. of wheels / no. driven wheels:	12 / 2
Drivetrain concept / max. speed (m/s):	Tracks, <1 m/s	Turning radius (cm):	0
Battery type / capacity (Ah):	LiPo, 5.2Ah	Total motor power (W):	244W
No. of sensors internal / external: Sensor type:	1 / 3 IMU, 2x Lidar, Camera		

Controller system software description (sensor data analysis, machine control etc.)
- Lidar distances below 75cm distance in average and horizontal distance calculated depending on angle - Lidar data of front and back to stay in the center of a row and find the next row - Lidar data of front for navigating into a row - PID-controller for motor controlling - IMU for turning angle at end of row
Controller system hardware description (motor controller, computer etc.)
- Motor Controller: 2x Beckhoff EL7037 - LED, Pump, Valve: 1x Beckhoff EL2008 - Computer: Embedded PC: i5-1135G7, 16GB RAM - Motor: 2x Stepper motor 24V, 3A
Short strategy description for navigation and applications
Navigation: Lidar distances to the side between 45° and 100° Lidar angle on each side, calculated the horizontal distance by angle. End of row turning with IMU and advancing to next row by count of Motor rotations and Lidar Application: Scanning with the back Lidar for plants at 90° angle of the vehicle within a window of 2x8,75° and spraying on the same axis
These are the commercial team sponsors & partners (if there are)
-

Bialystok Dynamics / AgroMaster

Team Name	Białystok Dynamics
Names of team members:	Bartłomiej Baldowski, Tomasz Chmielewski, Justyna Dobrzynska, Konrad Kubicki, Paweł Kusznier, Mateusz Ponikwicki, Karol Eugeniusz Sapiolko, Emil Szymczyk
Team captain's name:	Stanislaw Januszko
Instructor(s):	Kazimierz Dzierzek Maciej Recko
Institution:	Bialystok University of Technology
Department:	Faculty of Mechanical Engineering
Country:	Poland
Street / Number:	45A Wiejska St.
ZIP Code / City	15-351 Bialystok
Email:	m.recko@pb.edu.pl
Webpage:	---

INFORMATION ABOUT THE ROBOT			
W x L x H (cm):	roughly 55 x 50 x 60	Weight (kg):	roughly 50 kg

Commercial or prototype:	prototype	Total no. of wheels / no. driven wheels:	4/4
Drivetrain concept / max. speed (m/s):	all-wheel drive, tank driving mode	Turning radius (cm):	almost in-place
Battery type / capacity (Ah):	2x 80 Ah	Total motor power (W):	4 x 200 W
No. of sensors internal / external: Sensor type:	water-level sensor, ZED2i stereovision camera, 2x DUXO X13 webcams, LIDAR (probably RPLIDAR A3), Teseo VIC-3DA GPS module		

Controller system software description (sensor data analysis, machine control etc.)
ROS Noetic on Ubuntu 20.04, with custom and open-source packages (e.g. zed-wrapper, mapping), YOLOv4 object recognition network (as of now)
Controller system hardware description (motor controller, computer etc.)
Jetson Orin NX 16GB Dev-Kit, BLD-300B BLDC Motor Drivers, STM32 Nucleo board for watering system's control and GPS interfacing
Short strategy description for navigation and applications
The ROS navigation stack makes autonomous navigation in the cornfield possible, fed by data from the stereo camera, lidar and GPS module. Additional cameras on the sides allow us to explore the environment from the sides of the robot. For image object recognition, we use (as of now) YOLOv4 neural network. Our custom-trained image recognition neural network (made with Vertex AI on the Google Cloud Platform) is being tested.
These are the commercial team sponsors & partners (if there are)
Ministry of Education and Science, Republic of Poland

CARBONITE

Team Name	Carbonite
Names of team members:	Jonas Mayer, Lorin Meub, Janis Schönegg, Samuel Mannchen, Niels Fenkl, Robin Gramb
Team captain's name:	Klara Fauser
Instructor(s):	Lukas Locher
Institution:	Schülerforschungszentrum Südwürttemberg (SFZ) e.V.
Department:	Standort Überlingen
Country:	Germany
Street / Number:	Obertorstraße 16
ZIP Code / City	88662 Überlingen
Email:	sfz.carbonite@gmx.de
Webpage:	https://github.com/Team-Carbonite

INFORMATION ABOUT THE ROBOT			
W x L x H (cm):	42 x 70 x 68	Weight (kg):	13-15
Commercial or prototype:	Prototype	Total no. of wheels / no. driven wheels:	4/4
Drivetrain concept / max. speed (m/s):	1.6	Turning radius (cm):	ca. 90

Battery type / capacity (Ah):	LiPo/16 Ah	Total motor power (W):	ca. 410
No. of sensors internal / external: Sensor type:	2x laserscanner (SickTim 571), 1x camera (Jaigo 5000), 1x gyrosensor (Bosch BNO)		

Controller system software description (sensor data analysis, machine control etc.)
ROS
Controller system hardware description (motor controller, computer etc.)
Brushless RC-Motor (Platinium Brushless ⅛), intel nuc, 2x laserscanner (Sick Tim 517), 1x camera (Jaigo 5000), Nvidia Jetson AGX Xavier
Short strategy description for navigation and applications
The Carbonite navigates only with laserscanners and IMU. After the end of a row is detected the robot performs a Y-Turn and drives backwards into the next row. This is possible because the laserscanners are at the front and the back of the robot, thus making the robot basically symmetrical in terms of devices needed for navigation. For sensing and recognizing possible obstacles we plan to use an AI. In terms of spraying the plants we have not decided on a strategy yet.
These are the commercial team sponsors & partners (if there are)
Micro Macro Mint, Schülerforschungszentrum Südwürttemberg, Wilhelm Stemmer Stiftung, Sick AG

CERES Team / CERES II

Team Name	CERES Team
Names of team members:	Robert Alexaner Ellinghaus, Lucas Lüdiger, Natalie Peracha, Lars Pritzlaff
Team captain's name:	Robert Alexander Ellinghaus
Instructor(s):	Jochen Korn, Matthias Nießing
Institution:	FH Münster University of Applied Sciences
Department:	Department of Mechanical Engineering
Country:	Germany
Street / Number:	Stegerwaldstr. 39
ZIP Code / City	48565 Steinfurt
Email:	ceres@fh-muenster.de
Webpage:	https://www.fh-muenster.de/maschinenbau/labore/agrarroboter/agrarroboter.php

INFORMATION ABOUT THE ROBOT			
W x L x H (cm):	45 x 82 x 60	Weight (kg):	60

Commercial or prototype:	Prototype	Total no. of wheels / no. driven wheels:	4 / 4
Drivetrain concept / max. speed (m/s):	Four-wheel steering / 4	Turning radius (cm):	45
Battery type / capacity (Ah):	LiIon / 24,15Ah	Total motor power (W):	4 x 250 = 1000
No. of sensors internal / external: Sensor type:	4 x Intel RealSense D435 Depth Camera, 1 x IMU ICM-20948, 4 x motor encoder, 1 x battery voltage sensor, 1 x battery current sensor, 1 x temperature & humidity sensor, 2 x steering position sensor		

Controller system software description (sensor data analysis, machine control etc.)
The software of the robot runs on ROS Noetic, which is used as the basic framework. The functionality of the robot is set up on the use of several already existing ROS nodes as well as additionally added nodes. The additional nodes are implemented in C++ and Python. All robot operations are organized via a state machine, which coordinates between the different tasks (e.g., row drive, row turn).
Controller system hardware description (motor controller, computer etc.)
The chassis of the robot is based on aluminium extrusion profiles with four hoverboard wheels. The wheels are each mounted with individual suspension. On each axis, a stepper motor is installed to control the steering angle. Furthermore, the robot is equipped with a hitch to connect the trailer to the robot. Also, there is the possibility to carry additional equipment mounted to the aluminium profiles. The central computing unit is an Intel NUC. The wheels are controlled by two O-Drive motor controllers. To communicate with different sensors and actuators (e.g., for the hitch), numerous Arduino microcontrollers are installed in the robot.
Short strategy description for navigation and applications
For detection of the plants, the robot uses up to four depth cameras. Their data is evaluated by numerous algorithms to determine the position of the plants. Other ROS nodes use this information to tell the robot to navigate through the plant rows as well as to do a turn at the end of a row.
These are the commercial team sponsors & partners (if there are)
FH Münster University of Applied Sciences, Department of Mechanical Engineering

CHAPINGO / VOLTAN

Team Name	Chapingo		
Names of team members:	Noe Velazquez Lopez, David Ivan Sanchez Chavez,Guillermo Garcia Sanchez, Alan Hernandez Mercado, Monica Elizabeth Berrocal Aguilar, Omar Alexis Avendaño Lopez		
Team captain's name:	David Ivan Sanchez Chavez		
Instructor(s):	Noe Velazquez Lopez		
Institution:	Universidad Autónoma Chapingo		
Department:	Posgrado en Ingeniería Agrícola y Uso Integral del agua		
Country:	México		
Street / Number:	Km. 38.5 carretera México-Texcoco		
ZIP Code / City	56230 Texcoco		
Email:	nvelazquezl@chapingo.mx		
Webpage:	---		
INFORMATION ABOUT THE ROBOT			
W x L x H (cm):	50x74x46 cm	Weight (kg):	50 kg

Commercial or prototype:	Prototype	Total no. of wheels / no. driven wheels:	4/4 driven wheels
Drivetrain concept / max. speed (m/s):	Chain drive skid steer/ 1.35 m/s	Turning radius (cm):	32 cm
Battery type / capacity (Ah):	lead acid battery 12 V/12 Ah	Total motor power (W):	500 W
No. of sensors internal / external: Sensor type:	2 internals, 4 externals Imu, encoder/cameras, 2 lidar		

Controller system software description (sensor data analysis, machine control etc.)
The main software to control the robot is ROS. It communicates with Arduino code to receive signals from the encoder, the IMU, and the LiDARs. It utilizes machine vision for navigation between maize rows, obstacle recognition, and plant presence detection. The code is based on the OpenCV library.
Controller system hardware description (motor controller, computer etc.)
The robot has 2 electrical motors with 250 W of power. Each motor is connected to 2 wheels via chains to enable movement for one side of the skid steer. To control these motors the Sabertooth 2x60 motor driver is used. The models of the sensors include the rplidar a1m8, the LiDAR tf mini plus, and the IMU MPU6050. For remote control the robot is equipped with an FS-iA6 receiver and a Flysky i-6 controller. As for the vision system, it uses 2 Logitech c920 webcams. The computer running the main code in ROS is a Dell laptop with 8 GB of RAM, a 500 GB SSD, and an Intel i7-4510U processor with Ubuntu 18.04.
Short strategy description for navigation and applications
For navigation, the machine vision system detects the plants and calculates the midpoint between the rows. The motors move left or right based on the calculated point. Simultaneously the LiDAR detects the presence of maize. When the LiDAR stops detecting plants the robot turns and advances using data from the IMU and the encoder. The distance covered by the robot is measured by the encoder to determine the number of rows advanced, which is then compared with the required number to follow the route. To detect the presence of vegetation for water application another LiDAR is used to measure the distance between the robot and the plants. When there are no plants the distance is longer. This information combined with the camera detection and the rotary LiDAR, determines the presence of plants. For obstacle detection the robot uses the camera and analyses area, centroid, and colour characteristics to determine whether it is a deer, a human, or something else.
These are the commercial team sponsors & partners (if there are)
/

DTU MAIZERUNNERS / THOMAS

Team Name	DTU MAIZERUNNERS
Names of team members:	Emma Christine Lei Hovmand, Mads Peter Vindbjerg Højgaard, Emil Vejre Løwenstein, Emil Oliver Søndergård Ramovic, Søren Andreas Schmidt
Team captain's name:	Emil Oliver Søndergård Ramovic
Instructor(s):	Ole Ravn Nils Axel Andersen
Institution:	Technical University of Denmark
Department:	DTU Electro Department of Electrical and Photonics Engineering
Country:	Denmark
Street / Number:	Ørsteds Plads Bygning 343
ZIP Code / City	2800 Kongens Lyngby
Email:	LUAA@DTU.dk
Webpage:	https://electro.dtu.dk/

INFORMATION ABOUT THE ROBOT

W x L x H (cm):	35x65x60	Weight (kg):	~25kg (without water)
Commercial or prototype:	Prototype	Total no. of wheels / no. driven wheels:	4/2
Drivetrain concept / max. speed (m/s):	Ackermann 1 m/s	Turning radius (cm):	10cm
Battery type / capacity (Ah):	Lead Acid battery (Yuasa 597835) 2x7Ah	Total motor power (W):	N/A
No. of sensors internal / external: Sensor type:	Battery sensor Encoders for left and right driven wheel. Lidar in the front and the back, A camera (webcamera)		

Controller system software description (sensor data analysis, machine control etc.)
The robot has some navigation software implemented on it in advance, since it isn't the first time the robot is used at this competition. The results in the pasts years with this software haven't been perfect. This year's team will be optimizing and maybe change this software a bit. The current software plugin for the laser data returns a value and a position to the main loop which the robot uses as a reference point to where it should drive towards. This should be used in the first, second and fourth task. In the third and fourth tasks should the robot detect whenever the figure placed in front of it is a deer, human or unknown. To deal with this task, there is implemented a CNN to do image classification. The base model is MobileNet as to make the architecture as light as possible while still maintaining a high level of accuracy. The model is then trained on 2400 images of deer and humans. If the model predicts neither deer nor human, the image is classified as unknown.
Controller system hardware description (motor controller, computer etc.)
The robot consists of a NUC where the command-file is running. The robot also has some LED-strips, water pumps and a buzzer. This is controlled through a teensy with the NUC. The teensy have some appertaining power control circuits. The robot's two rear motors are two Maxon DC-motors. These are controlled by the NUC through a USB and two RS232 motor controllers. To steer the robot is two servos used to turn the front wheels. These are controlled by the teensy through a RS485 motor controller.
Short strategy description for navigation and applications
With the implemented plugins there is a good solution for navigation through the rows. This may still need some tuning. To get into the correct row is it needed to detect the rows when the robot is perpendicular to the rows. This is a bit tough as it stands right know, but a hardcoded solution is used now.
These are the commercial team sponsors & partners (if there are)

FARMBEAST

Team Name	FarmBeast	
Names of team members:	Urban Kenda Rok Friš Miha Kajbič Erik Rihter Gregor Popič Urban Naveršnik Kaja Žučko Katarina Lipovšek Lena Bojc Jaša Jernej Rakun Kokalj	Alen Juhart Valentin Podkrižnik Maja Glušič Tine Lubej Leopold Hauptman Rok Casar Marjan Dreier Timotej Plankar Gašper Majal Miha Mahor
Name team captain:	Urban Kenda, Miha Kajbič, Rok Friš	
Instructor(s):	prof. dr. Miran Lakota dr. Jurij Rakun dr. Peter Lepej	dr. Mitja Truntič dr. Simon Klančnik
Institution:	University of Maribor	
Department:	Biosystems engineering	
Country:	Slovenia	
Street / Number:	Pivola 10	
ZIP Code / City	Hoče	
Email:	**farmbeast@um.si,** jurij.rakun@um.si	
Webpage:	farmbeast.um.si, fkbv.um.si	

INFORMATION ABOUT THE ROBOT			
W x L x H (cm):	99 x 50 x 51	Weight (kg):	80
Commercial or prototype:	Prototype	Total no. of wheels / no. driven wheels:	4
Drivetrain concept / max. speed (m/s):	3	Turning radius (cm):	0
Battery type / capacity (Ah):	12	Total motor power (W):	800
No. of sensors internal / external: Sensor type:	Velodyne VLP-16 multichannel LIDAR ||SICK TIM310 LIDAR sensor,2 x RGBD camera, IMU (Xsens)		

Controller system software description (sensor data analysis, machine control etc.)
Linux Ubuntu, Robot Operating System
Controller system hardware description (motor controller, computer etc.)
Raspberry Pi 4 Model B (low level computer) + Intel NUC 7i7BNH (high level computer)
Short strategy description for navigation and applications
Custom infield navigation algorithm based on Velodyne and IMU readings.
These are the commercial team sponsors & partners (if there are)
SMTd.o.o, CLAAS, EMSISO d.o.o, Tuli d.o.o, IHS d.o.o, AzureFIlm d.o.o, ODrive Robotics, Inc., Rehar d.o.o.

FloriBot 4.0

Team Name	Team FloriBot
Names of team members:	Martin Haag, Marcel Holzwarth, Klaudius König, Paul Wolff
Team captain's name:	Paul Wolff
Instructor(s):	Benedict Bauer, Torsten Heverhagen
Institution:	Heilbronn University of Applied Sciences
Department:	Faculty of Mechanics and Electronics
Country:	Germany
Street / Number:	Max-Planck-Str. 39
ZIP Code / City	74081 Heilbronn
Email:	benedict.bauer@hs-heilbronn.de
Webpage:	www.hs-heilbronn.de/floribot

INFORMATION ABOUT THE ROBOT			
W x L x H (cm):	43 x 132 x 45	Weight (kg):	Approx. 60
Commercial or prototype:	Prototype	Total no. of wheels / no. driven wheels:	4/4

Drivetrain concept / max. speed (m/s):	All-wheel drive articulated steering / 2 m/s	Turning radius (cm):	37,5
Battery type / capacity (Ah):	Stiga SBT 5048 AE 2 x 5 Ah	Total motor power (W):	4 x 300
No. of sensors internal / external: Sensor type:	Encoder (IFM RM9003) for articulated joint, 2 x Lidar (TIM551), 2 x Depth camera (Intel Realsense D435i) and some more		

Controller system software description (sensor data analysis, machine control etc.)
ROS and PLC software
Controller system hardware description (motor controller, computer etc.)
SEW DHE41B and SEW CMP ELVCD, Nvidia Jetson AGX Xavier, Raspberry Pi 4B
Short strategy description for navigation and applications
Navigation in the rows is based on a simple algorithm that uses the robot's position relative to the centre of the rows to determine its speed and steering angle. The position of the robot relative to the centre of the rows is determined by using box filters that take advantage of the characteristics of monocultures. Navigation outside the corn field is done in a similar way.
These are the commercial team sponsors & partners (if there are)
SEW EURODRIVE, Ingenieurbüro Stöger, Agria-Werke GmbH

HELIOS evo

Team Name	Field Robot Event Design Team (FREDT)
Names of team members:	Enrico Schleef, Johann Thölking, Lisa Pullwitt, Marc Schernus, Tobias Lamping, Tristen Vaeckenstedt
Team captain's name:	Tobias Lamping
Instructor(s):	Dr.-Ing. Jan Schattenberg
Institution:	Technische Universität Braunschweig
Department:	Institut für mobile Maschinen und Nutzfahrzeuge
Country:	Germany
Street / Number:	Langer Kamp 19a
ZIP Code / City	38106 Braunschweig
Email:	fredt.tubs@gmail.de
Webpage:	www.fredt.de

INFORMATION ABOUT THE ROBOT			
W x L x H (cm):	35 x 69 x 40	Weight (kg):	30 kg
Commercial or prototype:	Prototype	Total no. of wheels / no. driven wheels:	4/4
Drivetrain concept / max. speed (m/s):	4WD / 3,5m/s	Turning radius (cm):	75 cm
Battery type / capacity (Ah):	Li-ION 6000 mAh NiMH 4500 mAh	Total motor power (W):	250 W

No. of sensors internal / external: Sensor type:	2x LIDAR: SICK TIM 571 Odometry Unit Camera: 2 x Intel RealSense

HELIOS evo is the current robot generation of the FRED-Team. It is based on our proven chassis with four wheel drive and all wheel ackermann steering.
The main component of Helios evo is the multifunctional body in which the central electrical distribution and battery-management-unit as well as the agricultural rear lift system with 20 kg load capacity are integrated. The rear lift system is equipped with integrated electrical- and fluid-lines. The vehicle body also includes the main computer and the cooling and light system. A dual LIDAR Sensor System is used for improved driving stability.

Controller system software description (sensor data analysis, machine control etc.)
Two LIDAR at different heights are used to approximate the distances between the rows of maize plants. In addition, it is easier to recognise obstacles such as leaves from different angles. By processing, it is possible to determine the centre of the robot to the plant rows to predict how the robot can drive through the rows as fast as possible.
Controller system hardware description (motor controller, computer etc.)
The navigation runs on a Gigabyte Barebone with i7-4770R, 16GB RAM, 256 GB SSD. It contains steering the motor for driving and steering servos for turning as well as data analysis by several sensors, which are localised in front of the robot. In addition, there are another micro-controller (ESP-WROOM-32) which are used for battery management and all other functions concerning task-implements (e.g. servos, rear power lift, sprayer, ...). It is connected to the main Computer via WIFI.
Short strategy description for navigation and applications
The goal for the first task is to cover as many rows as possible based on the given row pattern and the available time. In the second task, the goal is to detect all the gaps in the rows and spray them accurately at the highest possible speed. For the third task we use an opensource-based AI to detect people, deer or other things. We train the AI with images from the internet. In task four, our goal is to recognise all objects correctly and decide correctly what to do. For reverse driving, we want to use camera-based driving. The goal for task five is to come up with a new agricultural idea to detect sick plants and remove them.
These are the commercial team sponsors & partners (if there are)
Technische Universität Braunschweig INSTITUT FÜR mobile Maschinen und Nutzfahrzeuge

Kamaro Engineering e. V. / Beteigeuze

Team Name	Kamaro Engineering e.V.
Names of team members:	Johannes Barthel, Johannes Bier, Thomas Bollenbach, Edvardas Bulovas, Kevin Daiß, Fabian Duttlinger, Philipp Fissler-Pechtl, Thomas Friedel, Antonio Georgi, Stephan Göhner, David Grishchuk, Artin Hachikyan, Adrian Hauptmannl, Aysun Levin Hyudyaim, Mathias Krohmer, Jonas Lewandrowski, Michael Liu, Konstantin Lutz, Marwin Madsen, David Mall, Olivia Mammadova, Andreas Nettekoven, Karolina Polnik, Richard Reminger, Philipp Román, Sinan Sarikaya, Lea Schulze, Leon Tuschla, Juliane Weiß, Mirco Werner, Erik Wustmann, Jakob Zimmermann
Name team captain:	Leon Tuschla, Johannes Bier
Instructor(s):	Electronics: Stephan Göhner Mechanics: Fabian Duttlinger Software: Johannes Bier Organization: Kamaro Engineering e.V.
Institution:	Kamaro Engineering e.V. at Karlsruhe Institute of Technology
Department:	MOBIMA/ FAST
Country:	Germany
Street / Number:	Rintheimer Queralle 2, c/o Lehrstuhl für mobile Arbeitsmaschinen
ZIP Code / City	76131 Karlsruhe
Email:	mail@kamaro-engineering.de
Webpage:	https://kamaro-engineering.de/

THE MACHINE			
W x L x H (cm):	50 x 85 x 40	Weight (kg):	Approx. 40 kg
Commercial or prototype:	Prototype	Total no. of wheels / no. driven wheels:	4/4
Drivetrain concept / max. speed (m/s):	4-Wheeldrive/ 2m/s	Turning radius (cm):	50
Battery type / capacity (Ah):	6 cell LiPo/ 10 Ah	Total motor power (W):	main drive: 220W
No. of sensors internal / external: Sensor type:	2x LIDAR SICK TIM571, 2x absolute encoder Pepperl & Fuchs CSS36M, IMU & Magnetometer BNO055, Webcam Camera		

Controller system software description (sensor data analysis, machine control etc.)
The robot software is implemented on top of the Robot Operating System (ROS) Software Stack. This means that the software is separated into so called nodes which solve small parts of the overall problem. There is a crawl row node keeping the robot in the middle between two rows of corn and a turn node that manages the switching between the rows. A detection node is using the camara data to detect cans and dandelions on the field and add them to the created map. A state machine orchestrates the nodes to achieve the correct interplay for the given tasks.
Controller system hardware description (motor controller, computer etc.)
Mechanical: To full fill the requirements of a robot driving in a field the drive chain was designed as a 4-Wheeldrive with a single, central electric motor that can provide torque up to 9 Nm per wheel. The power transmission flows on two self-designed differentials in the front and the back of the robot. Each axle mounting has its own suspension ensuring a smooth ride in rough terrain. The front and back axis can be steered independently therefore also diagonal movements are possible. Electrical: The central computing unit is an Nvidia Jetson Xavier NX provided by ViGEM executing ROS. We also use an extra x86 computer located in the bowel of our robot. For almost all electric peripherals, we use the middleware RODOS developed by the University of Wuerzburg that runs on a STM32-Controller. The communication between the Jetson Xavier NX and the peripherals is CAN-BUS-based with a RODOS-ROS-Bridge on the PC-Side. The BUS-topology allows also for direct communication between peripherals.
Short strategy description for navigation and applications
We will use the LiDAR installed at the front to navigate between the rows of maize plants. We have a newly designed spraying system for Task 2, where we use the LiDAR to detect the row gaps and pressurized tank to water the plants. For Task 3 and 4 we trained a neural network. As our Freestyle task we are planning to present autonomous harvesting of strawberries.
These are the commercial team sponsors & partners (if there are)
Companies: SICK, Dunkermotoren, CONEC, Pepperl+Fuchs, KissSoft, ViGEM Institutes at the KIT: MOBIMA/FAST, WBK

NMBU - Robotics

Team Name	NMBU - Robotics
Names of team members:	Bård Tollef Pedersen, Henrik Nordlie, Lavanyan Rathy, Peder Ørmen Bukaasen, Tor Erik Aasestad
Team captain's name:	Tor Erik Aasestad
Instructor(s):	Weria Khaksar
Institution:	Norwegian University of Life Sciences
Department:	Faculty of Science and Technology
Country:	Norway
Street / Number:	Drøbakveien 31
ZIP Code / City	1430 Ås
Email:	weria.khaksar@nmbu.no
Webpage:	https://www.nmbu.no/en/faculty/realtek/research/groups/roboticsandcontrol

INFORMATION ABOUT THE ROBOT			
W x L x H (cm):	43,0 x 50,8 x 25,0	Weight (kg):	17
Commercial or prototype:	Jackal from clearpath robotics	Total no. of wheels / no. driven wheels:	4 / 4
Drivetrain concept / max. speed (m/s):	Four-wheel differential drive / 2.0	Turning radius (cm):	N/A

Battery type / capacity (Ah):	Lithium Ion/ 11,25	Total motor power (W):	500
No. of sensors internal / external: Sensor type:	Camera, 3d-lidar, imu,		

Controller system software description (sensor data analysis, machine control etc.)
We are using ros1, with different packages for handling point cloud data, imu information, and Laserscan data.
Controller system hardware description (motor controller, computer etc.)
We are using the stock jackal platform; we are also adding some logic for watering using an Arduino.
Short strategy description for navigation and applications
Using 3d-lidar to navigate down rows. Using navigation stack and lidar data to deal with both turning and row skipping. Hopefully we can use lidar for dealing with holes in rows, plus how we handle the watering system.
These are the commercial team sponsors & partners (if there are)
N/A

We haven't recieved the robot yet, but we think it looks like this:

Robatic / Bullseye

Team Name	Robatic
Names of team members:	Anne-Corine Visser, Lars van der Veer, Kyle Huibregtse, Sophie Sliepenbeek, Thijmen Tukker, Colin Groot, Robin van Wegen, Jan-Willem Veldhuijsen, Merel Stevens, Jeroen Cox, Eline Pickott
Team captain's name:	Kyle Huibregtse
Instructor(s):	Sam Blaauw, Rick van Essen
Institution:	Wageningen University and Research
Department:	Farm Technology Group
Country:	The Netherlands
Street / Number:	Droevendaalsesteeg / 4
ZIP Code / City	6708 PB / Wageningen
Email:	Robatic.bullseye@gmail.com
Webpage:	Robatic.nl

INFORMATION ABOUT THE ROBOT

W x L x H (cm):	40 x 135 x 55	Weight (kg):	40
Commercial or prototype:	Prototype	Total no. of wheels / no. driven wheels:	4 / 4
Drivetrain concept / max. speed (m/s):	The theoretical unloaded max. speed is 1.6 m/s at 24V.	Turning radius (cm):	0
Battery type / capacity (Ah):	2x 7.5 Ah	Total motor power (W):	4x 150W
No. of sensors internal / external: Sensor type:	**External** Lidar: 2x Camera 1x Ultrasonic 2x **Internal** IMU sensor 1x		

Controller system software description (sensor data analysis, machine control etc.)
The software runs in Robot Operating System 2 (ROS2) Kinetic on Ubuntu 22.04
Controller system hardware description (motor controller, computer etc.)
The Bullseye uses a Jetson. This compact computer makes it possible to run multiple neural networks parallel to each other. It also uses an Arduino Nano which is a microprocessor that is used to control the emergency brake. For steering, it uses a wheel encoder to give the wheels the angles needed for each turn it has to make.
Short strategy description for navigation and applications
The Bullseye navigates through rows with the use of Lidar sensors. These Lidars sensors sense the distance between the row and the robot, and also if the row is at its end.
These are the commercial team sponsors & partners (if there are)
Lemken, Steketee, Agrifac, Kverneland, Claas, Konst Research b.v.

TEAM MERO / ERDBOT

Team Name	Team MERO
Names of team members:	Rakesh Bojanki, Saurabh Yeola, Sukumar Mannem, Shaili Gupta, Dhaval Lad, Hemanth Kumar Mandava, Mayank Yogesh Khandelwal, Rahul Guptha Suryadevara
Team captain's name:	Rahul Guptha Suryadevara
Instructor(s):	Prof. Frank Schrödel
Institution:	Hochschule Schmalkalden
Department:	MERO
Country:	GERMANY
Street / Number:	Blechhammer 9
ZIP Code / City	98574
Email:	teammero2023@gmail.com
Webpage:	/

INFORMATION ABOUT THE ROBOT			
W x L x H (cm):	40 x 60 x 35	Weight (kg):	15 kg
Commercial or prototype:	Prototype	Total no. of wheels / no. driven wheels:	4 / 2

Drivetrain concept / max. speed (m/s):	2 Wheel Differential Drive/1.2 m/s	Turning radius (cm):	
Battery type / capacity (Ah):	Lead Acid / 7.2 Ah	Total motor power (W):	85 W (2 x 42.5)
No. of sensors internal / external: Sensor type:	IMU x 1, 2D LIDAR x 1, Camera x 2, Encoders x 2		

Controller system software description (sensor data analysis, machine control etc.)
The Robot software runs on ROS Noetic, With Sensors publishing data on the Computer using Serial bus Communication. Several ROS nodes (turning, moving) are used to set up the Robot functionality. The moving node is used to crawl the robot between the rows of the field and the turning node helps to take a turn to the next row at end of the field row.
Controller system hardware description (motor controller, computer etc.)
Mechanical: The Robot has 2 powered wheels, each driven by a 12V DC motor. The Turning radius was minimum due to Differential Drive Movement. Electronics: The main Computing unit is Nvidia Jetson Xavier for executing ROS and Vision tasks. We also use Arduino Mega as a Low-level onboard computer to perform other peripheral tasks.
Short strategy description for navigation and applications
ERDBOT uses a simple algorithm that navigates through the point cloud created by LIDAR when it detects Maize plants. It uses the position of the robot and steers it to the middle of the row. When the robot reaches the end of the row. The robot turns 90 degrees, moves the length of the next row, takes turns, and navigates to the next row.
These are the commercial team sponsors & partners (if there are)
HOCHSCHULE SCHMALKALDEN, SICK Vertriebs-GmbH, Rennsteig Werkzeuge GmbH,CLAAS Foundation

Program - June 12th to 15th, 2023

Monday, June 12th

12:00 – 18:00	Team registration / testing
18:00 – 19:00	Briefing of team captains
18:00 – 20:00	Dinner

Tuesday, June 13th

07:00 – 9:00	Breakfast
09:00 – 10:00	Welcome note
10:00 – 12:00	1st Task
12:00 – 14:00	Lunch
14:00 – 16:00	2nd Task
18:00 –	Awarding ceremony
18:00 – 20:00	Dinner

Wednesday, June 14th

07:00 – 9:00	Breakfast
10:00 – 12:00	3rd Task
12:00 – 14:00	Lunch
14:00 – 16:00	4th Task
18:00 –	Awarding ceremony
18:00 – 20:00	Dinner

Thursday, June 15th

07:00 – 9:00	Breakfast
10:00 – 12:00	5th Task
12:00 –	Awarding ceremony, Farewell

A LIST OF ROBOTS

University of Maribor

Faculty of Agriculture and Life Sciences