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International FRE Field Robot Event

Field Robot Event

International Contest

19th edition

14th – 16th June 2022

Program Booklet

DLG Feldtage
Meet the crop professionals

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Index

Acknowledgement 3

Welcome 5

Contest Task 1, 2 & 3
General Rules, Description and Assessment.................................... 6

Team & Robot Descriptions..19

Team HX – TH Ostwestfalen – Lippe 18

Team Carbonite – SFZ Südwürttemberg e.V. 20

AIRLab Polimi – Politecnico di Milano..................................22

HELIOS evo – TU Braunschweig 24

Robatic Group – Wageningen University and Research.........26

CERES II – FH Münster University of Applied Sciences...........28

FLORIBOT – Heilbronn University of Applied Sciences...........30

Acorn – University Osnabrück 32

ATH Rover – University of Hohenheim 34

FarmBeast – University of Maribor.......................................36

RON – Private Project Group 38

Kamaro Engineering – KIT Karlsruhe....................................40

Acknowledgements

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Special thanks to **Sylvia Looks** from the CLAAS FOUNDATION for extra funding of teams coming first time or coming with a new machine to the competition

Welcome to the Field Robot Event 2022!

This year the 19th Field Robot Event (FRE) will be held virtually in a simulation and in a real field. After a complete virtual event 2021 the robots are back in the field.

Thirteen international teams from Europe have registered for 2022, hence thirteen virtual and real robots will compete in finding automated solutions for agricultural tasks. We wish all teams to have good ideas for solving problems (challenges!), good success in implementation and fun & good luck!

The International Field Robot Event has been held every second year since 2014 together with the DLG Field Days. This cooperation will be continued this year. The FRE event in simulation and real field will be live-streamed on DLG's digital platform. You just need to register for free: Watch the three-day robot event on www.dlg-connect.com.

The organizing team 2022

Hans W. Griepentrog, Sam Blaauw, Rick van Essen

You find the description of tasks and rules here:
https://www.fieldrobot.com/event/index.php/contest/tasks/

More general information on the internet: http://www.fieldrobot.com/event/

Field Robot Event 2022 – The Tasks and Rules

Simulation and Field Contest from 14th to 16th June 2022

Together with the DLG-Field Days, Germany

Remark: The organizers tried to describe the tasks and assessments as good and fair as possible, but all teams should be aware of that we might need to modify the rules before or even during the contest! These ad hoc changes will always be decided by the jury members.

Aim of the Field Robot Event 2022

The aim of the Field Robot Event 2022 is to compare robot programming and behaviors in a modeled and real field. That's why we decided to go for a hybrid format. We will try to minimize the difference between the virtual field and the real field as much as possible. Therefore, it will be a big challenge for the organizers especially to create and adapt the field simulations including crop plants, weeds and other objects.

All tasks runs in simulation, field performance and awarding will be broadcasted to the internet by the platform DLG connect with access after free registration.

The simulation will be during the morning and the field runs will be during the afternoon. Each task will be conducted for simulation AND for a real field.

Comments for the simulation contest:

A model of a standard robot (Jackal CLEARPATH ROBOTICS, German dealer NEXT company) will be provided for those teams who want a model. Teams can also come with their own machine models. The models must be realistic in function and physics (kinematics, sensing and other abilities). Basic parameters must be considered and respected.

For those teams who are not coming to the event personally, we offer the opportunity that their codes can also be tested in the real field during the afternoon runs.

Teams should inform us about what sensors etc. they want to use. The organizers will decide about if the requested components can be used. After the organizers agreed to the use of a component they will ensure that they can be executed within the composed environments (simulation).

All source codes (models for sensors etc.) should be send to the organizing team and made public before the event. In general, we want to promote the use of open source sensors.

More information on the webpage: https://www.fieldrobot.com/event/

0. Introduction

The organizers expect that a general agreement between all participating teams is that the event is held in an "Olympic Manner". The goal is a fair competition, without any technological or procedural cheating or gaining a competitive advantage by not allowed technologies. The teams should even provide support to each other with all fairness. Any observed or suspected cheating should be made public immediately.

The jury members are obliged to act as neutrals, especially when having relations to a participating team. All relevant communication will be in English. For pleasing national spectators, the contest moderation could partly switch to a national language.

If teams come with more than one machine the scoring, ranking and awarding will always be machine related and not team related.

During the machine runs for each task the team members are not allowed to be in the inner contest area where the maize plants are and close to the robot during the performance. If the robot performance fails, it has to be stopped from outside with a remote switch. To enter the inner contest area is only allowed after (!) the robot has stopped. The control switch activating team member then can go to the machine and manually correct it. When the team member has left the inner contest area only then the robot is allowed to continue its operation. This procedure shall promote the autonomous mode during the contest and make the performance more attractive to spectators.

All participating teams must contribute to the event proceedings with an article describing the machine in more details and perhaps their ideas behind it or development strategies in general. The submission of text is after the event.

0.1. General rules

The use of a GNSS receiver is not allowed except for the Free Style. The focus for the other tasks in terms of localization shall be on relative positioning and sensor-based behaviors.

Crop plants

The crop plants for the tasks is maize (corn) or *Zea Mays*[1] . The maize plants will have a height of approximately 20 - 40 cm. The concrete appearance of the crop plants is depending on the location specific growing conditions and varies from year to year.

Damaged plants

A damaged plant is a maize plant that is permanently bent, broken or uprooted. The decision about a maize plant to be damaged by a machine will be made by the jury members or assistants.

Parc fermé

During the contests, all robots have to wait in the parc fermé from the beginning on. Therefore, no more machine modification to change the machine performance is

[1] Plant density 10 m^2, row width of 0.75 m, plant spacing 0.133 m

allowed during the task runs with regard to fairness. All PC connections (wired and wireless) have to be removed or switched off and an activation of a battery saving mode is recommended. This shall avoid having an advantage not being the first robot to conduct the task. The starting order will be random. When a robot will move to the starting point, the next robot will already be asked by the parc fermé officer to prepare for starting.

Navigation

The drive paths of the robots shall be between the crop rows and not above rows. Large robots or robots which probably partly damage the field or plants will always start after the other robots, including the second chance starting robots. However, damaged plants will be replaced by spare ones, to always ensure the same operation conditions for the robots.

0.2. General requirements for all robots

Autonomous mode

All robots must act autonomously in all tasks except for the freestyle. In the freestyle a full autonomous mode would be perfect but perhaps hard to realize. Driving by any remote controller during the other tasks is not allowed at any time. This includes steering, motion and all features that produce movement or action at the machine. Stopping and starting function for manual corrections of the machine is the only exception.

During start, the robot is placed at the beginning of the first row. The starting line is marked with a white cross line. Any part of the robot must not exceed the white line in the start. For signaling the start and end of a task there will be a clear acoustic signal. After the start signal, the robot must start within one minute. If the robot does not start within this time, it will get a second chance after all other teams finished their runs, but it must - after a basic repair - as soon as possible brought back into the parc fermé. If the robot fails twice, the robot will be excluded from the task starting list.

Start & Stop Controller

All robots must be equipped with and connected to one wireless remote START/STOP controller. Additional remote displays are allowed but without user interaction, e.g. notebook or laptop.

Preferably, the remote controller is a device with two buttons clearly marked START and STOP. Alternatively, the coding may be done with clear green and red colors.

It is allowed to use a rocker switch with ON/OFF position with hold, if the ON and OFF are clearly marked with text in the remote controller.

Any button of the remote controller may not be touched for more than one second at a time. In other words, a button, which has to be pressed all the time, is not allowed.

The remote controller may contain other buttons or controls than the required/allowed START/STOP inputs, but no other button may be used at any time during any task.

Before the start of any task, the remote controller must be placed on the table that is located at the edge of the field. One member of the team may touch the START and STOP inputs of the remote controller. The possible remote display must be placed on the same table too.

The remote controller must be presented to the Jury members before the run. A jury member will watch the use of the START/STOP remote controller during the task execution. Other remote controllers besides START/STOP controller are strictly prohibited to be used at any time.

In each task, the robot must be started by using the remote controller START input, not pressing any buttons on the robot itself.

During any task, while the robot is stopped in the field by using the remote controller, it is allowed to use any buttons of the robot itself, e.g. to change the state of the navigation system.

Implementation note: If using Logitech Cordless Gamepad or equivalent as a remote controller, the recommended practice is to paint/tape one of the push button 1 green and push button 2 red, to mark START and STOP features.

Manual correction of the robot
One team member is allowed to enter the field after the same (!) team member has pressed the STOP button of the remote controller and the robot has completely stopped (no motion). It is recommended to install some indicator onto the robot to see that the robot is in STOP mode before entering the field in order to avoid disqualification.

The START/STOP operator is also responsible for the eventually manual robot corrections. Due to the fact that it can be difficult for him/her to monitor the robot's behavior from a large distance, another team member can be inside the 2 m area between a red textile tape and the crop plant area (see picture 1 and 2 at the end of this document). This second team member could give instructions to the operator, but this supporting person is only an observer and is not allowed in any case to enter the crop plant area or interact with the robot.

After leaving the remote control on the table, the operator is allowed to rotate - not to move - the robot in the field. The only exception for moving is when the robot may need to get back to the path if a wheel or track of the robot has collided stem of maize plant, to avoid further damage of plants. Carrying the robot is only allowed after significant navigation errors in order to bring it back (!) to the last correct position and orientation.

0.3. Awarding and Prizes

The performance of the competing robots will be assessed by an independent expert jury committee. Beside measured or counted performance parameters, also creativity and originality (freestyle) will be evaluated. There will be an award for the first three ranks of each task. All tasks together will yield two overall competition winners: one for simulation and one for the field competition. Points will be given as follows:

Rank	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	etc.
Points	30	28	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	etc.

Participating teams result in at least 1 point, not participating teams result in 0 points. If two or more teams have the same number of points for the overall ranking, the team with the better placements during all tasks will be ranked higher.

1. Task 1 “Navigation”

1.1. General description

For this task, the robots are navigating autonomously through a modeled and real maize field. Turning has to follow adjacent rows for track 1 to 7. From exiting track 7 the robot has to 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 the Appendix.

1.2. Virtual and Field Environment

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 7 – the robot has to follow a particular given turning and row pattern. This pattern will be made available 15 minutes before the contest starts for the real-world contest. In the simulation, the pattern is made available in the ‘driving_pattern.txt’ file in the `map` folder of the `virtual_maize_field` package of the robot container. The content of this file may look as an example like:

S – 1L – 1R – 3L – 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.

1.3. Rules for robots

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

1.4. Assessment

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. (This year example 10 tracks x 10 m = 100 m max. distance, means a penalty of 2 m per damaged plant.)

2. Task 2 "Sensing, Mapping and Object Removal"

2.1. General description

The robots shall detect objects as weeds (5 dandelions) and beer cans (5 objects as examples for waste) and map or geo-reference them. The coordinate system shall be locally in horizontal field dimensions. Good row navigation is required. There will be ten (10) objects in total distributed across the virtual and real field.
The robot has to generate a file (pred_map.csv) with detected objects and their coordinates relative to the given reference points (pillars with QR code). The reference point of the coordinate system (0,0) is in the center of the field. Each line in the submitted file shall represent an object together with the coordinates x and y in horizontal plane in meters with 3 decimal points. Extra points can be obtained for object classification of weed or litter also indicated in the file. The file layout as an example is:

```
X,Y,kind
1.412,2.301,weed
-2.352,3.321,litter
1.873,-1.322,weed
etc...
```

After the run, this file should be given to the jury immediately on a USB-stick from the organization. In the simulation, this file should be saved in the `map` folder of the `virtual_maize_field` package in the robot container. The removal of waste to headlands gains also extra points, see below.

2.2. Virtual and Field Environment

Objects are realistic weeds and cans e.g. of beer with different brands and colors. The objects will be placed randomly across the field. No objects are located on the headlands. The reference point of the relative coordinate system will be in the center of the field and not marked. The pillars show a QR code with the name of that pillar. The relative coordinates of the pillars will be provided to the teams on forehand in the field contest. In the simulation, the coordinates of the pillars will be provided in the markers.csv file in the map folder of the 'virtual_maize_field' package.
In the field, the robot should be able to make two different loud distinct sounds when it detects a weed or can. Both sounds should be different in order to indicate which kind of object was found. In the simulation, when the robot detects an object, it should publish the object type ('weed' or 'litter') to the '/fre_detections' topic. This will spawn a marker in the simulation above the robot position.

2.3. Rules for robots

The maximum available time for the mapping run is 3 min, but if the robot successfully moves an object to the headline it will gain 1 min of time. This is to promote the waste removal and not to get punished for this useful action.

2.4. Assessment

The jury calculates and assesses the accuracy of the provided and mapped objects:

- Detected object and right category (true positive)	5 points
- Detected object wrong category (false positive)	minus 5 points
- Mapped object position to true position	points = f (distance error)

$$\text{Points} = f(x_{error}) = \begin{cases} 15 \quad if\ x \leq 2\ cm \\ 15.56 - 0.2817 * x \quad if\ x \leq 37.5\ cm \\ -5 \quad if\ x > 37.5\ cm \end{cases}$$

with x_{error}: distance error or Euclidean distance

Crop plant damage by the robot will result in a penalty of 4 points per plant.

2.5. Additional task for the field runs - Removal of waste objects

The robot can remove the 5 waste objects and place them outside the crop area on the headlands. The Jury or the simulator registers and assesses the number of objects where they are remaining after the run:

- Object picked up	3 points per object
- Object delivered to headlands	6 points per object AND a time bonus of 1 minute

The robot is allowed to push the object to the headland, but without a clear act of picking up, it will only earn points for the delivery. Crop plant damage by the robot will result in a penalty of 4 points per plant. The total travelled distance will not be assessed.

3. Task 3 "Freestyle"

3.1. General description

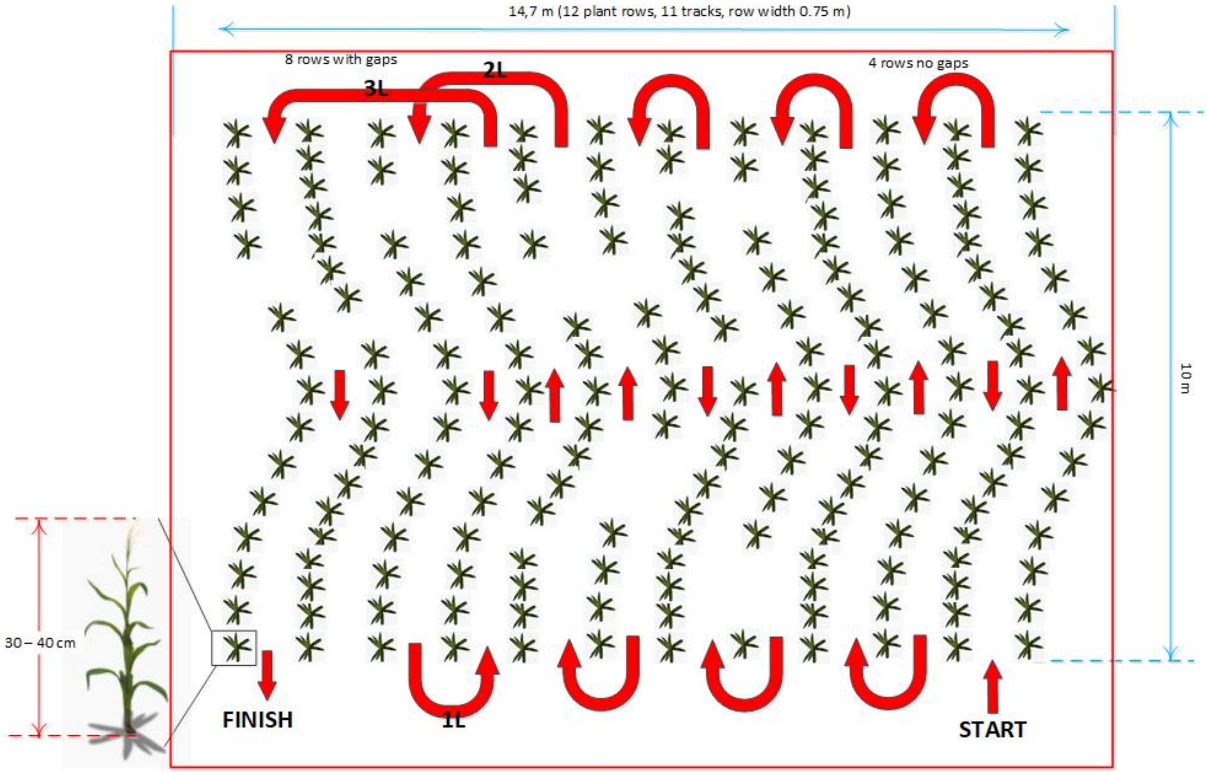
Teams are invited to let their virtual and real robot perform a freestyle operation at their home institution or in the virtual environments or on the events venue. The explanation as well as the performance shall be transmitted online via internet to the jury and the spectators. The team has to explain 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.

3.2. Assessment

The jury will assess by points P the
P_1 : agronomic idea (originality)
P_2 : technical complexity
P_3 : robot performance
Points P will be given from 0 (insufficient) to 10 (excellent) for each criterion (P_1, P_2 and P_3). The total points will be calculated using the following formula:
P_{final} points = $P_1 + P_2 + 2\ P_3$ (double weighing on performance)

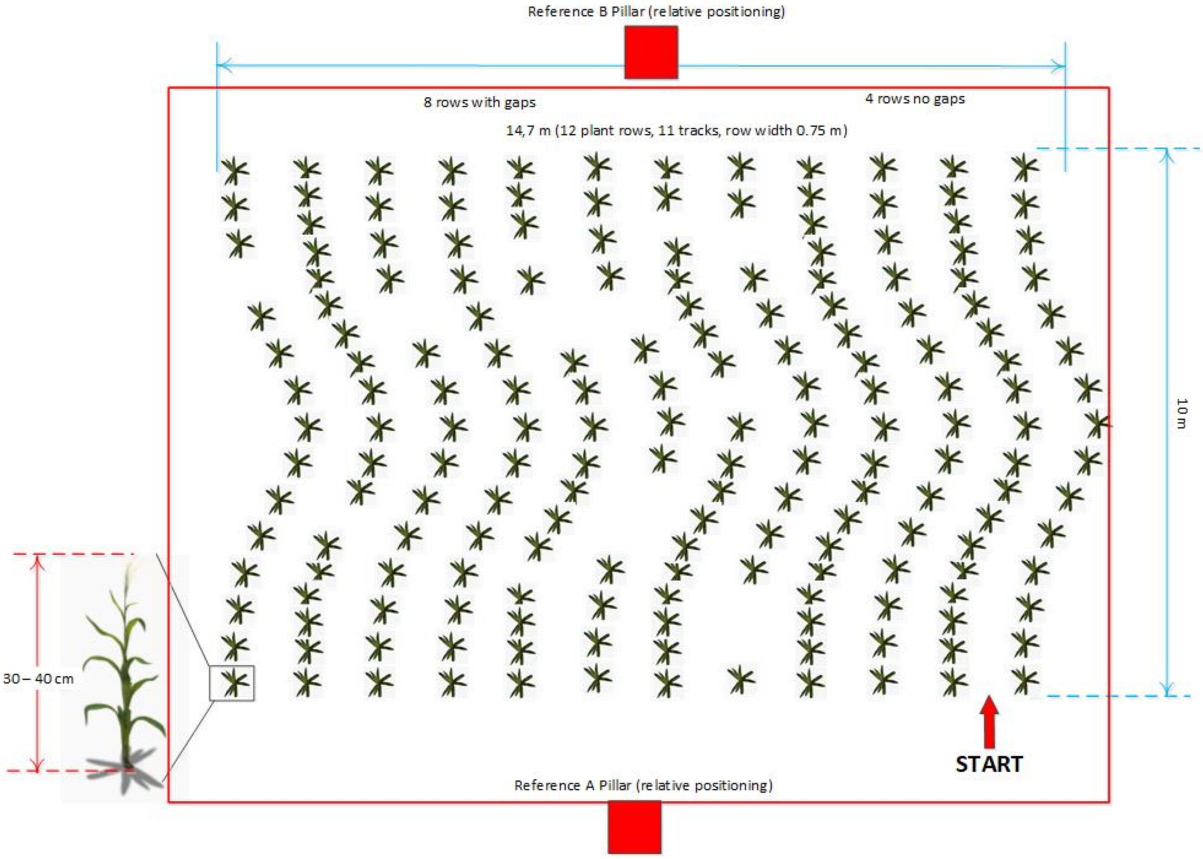
Appendix

Concept of field structure for task 1 (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.

Concept of field structure for task 2



Track 1 to 3 with no gaps, track 4 to 11 with gaps. The 10 objects (5 weeds and 5 cans) will distributed randomly within the field, but not on headlands. The reference point of the coordinate system is in the center of the field (0,0). The pillars will have coordinates as (Xpillar1,Ypillar1) for the upper one and (Xpillar2,Ypillar2) for the lower one.

These artificial dandelions will be used in the task 2. There will be 5 dandelions and 5 cans as litter within the field. There will be variations within the 5 dandelions in number of blossoms (0 to 5). At least one can will be damaged.

Hans W. Griepentrog, Sam Blaauw, Rick van Essen 07.06.2022

Participating Teams

1. Team HX

Team members:	Matthias Valentin Meer, Ronja Nickeleit		
Team captain:	Ronja Nickeleit		
Instructor(s):	Prof. Dr. Wrenger		
Institution:	Technische Hochschule Ostwestfalen-Lippe		
Department:	Studiengang Precision Farming		
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Email:	ronja.nickeleit@stud.th-owl.de		
Webpage:	-		

THE MACHINE			
W x L x H (cm):	61,4 x 72,0 x 82,0	Weight (kg):	65
Commercial or prototype:	Commercial (Robotnik)	Number of wheels:	4 Wheels
Drivetrain concept / max. speed (m/s):	3	Turning radius (cm):	0
Battery type / capacity (Ah):	15	Total motor power (W):	4 x 500
No. sensors internal / external: Sensor(s) type(s):	Internal: 1 (IMU) External: 4 (2x 3D-Camera, 2x 2D-Lidar)		

Controller system software description (sensor data analysis, machine control etc.)
Open architecture ROS, PC with Linux integrated

Controller system hardware description (motor controller, computer etc.)
Internal PC

Short strategy description for navigation and applications
Detection of rows via image processing and lidar.

These are the commercial team sponsors & partners (if there are)
-

2. Carbonite

Team members:	Jonas Mayer, Lorin Meub, Janis Schönegg, Junus Hirner, Samuel Mannchen		
Team captain:	Klara Fauser		
Instructor(s):	Lukas Locher		
Institution:	Schülerforschungszentrum Südwürttemberg (SFZ) e.V.		
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Street / Number:	Obertorstraße 16	ZIP Code	88662
Email:	sfz.carbonite@gmx.de		
Webpage:	https://sfz-bw.de/ueberlingen		

THE MACHINE			
W x L x H (cm):	47 x 71 x 77	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/16Ah	Total motor power (W):	Ca. 410
No. sensors internal / external: Sensor(s) type(s):	2x laserscanner (Sick Tim 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)

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 detecting weeds or trash in the field we plan to use either color recognition or an AI.

These are the commercial team sponsors & partners (if there are)
Micro Macro Mint, Schülerforschungszentrum Südwürttemberg, Wilhelm Stemmer Stiftung, Sick AG

3. AIRLab Polimi / grasslammer

Team members:	Paolo Cudrano, Emanuele Locatelli, Simone Mentasti, Matteo Nicolò, Samuele Portanti, Alessandro Romito, Sotirios Stavrakopoulos, Gülce Topal, Mirko Usuelli, Matteo Zinzani		
Team captain:	Paolo Cudrano, Simone Mentasti		
Instructor(s):	Matteo Matteucci		
Institution:	Politecnico di Milano		
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Webpage:	https://airlab.deib.polimi.it/		

THE MACHINE			
W x L x H (cm):	43 x 50.8 x 25	Weight (kg):	19 (approx.)
Commercial or prototype:	Commercial: Clearpath Jackal (virtual and remote)	Number of wheels:	4 / 4
Drivetrain concept / max. speed (m/s):	4WD / 2.0 m/s	Turning radius (cm):	0
Battery type / capacity (Ah):	Lithium Ion 270 Wh	Total motor power (W):	500
Sensor(s) type(s) used:	2 x 2D LiDAR Sick LMS1xx 3 x depth camera Intel® RealSense™ D435 Clearpath Jackal IMU		

Controller system software description (sensor data analysis, machine control etc.)
The robot software is based on Robot Operating System (ROS) Noetic, with several interacting nodes programmed in C++ and Python. Part of the navigation is performed using ROS packages move_base and gmapping. The overall system has several states, and transitions between these states determine its behavior. Camera images are processed through a Convolutional Neural Network (CNN). The odometry is provided by the robot pre-loaded software.

Controller system hardware description (motor controller, computer etc.)
Simulated and standard Clearpath Jackal hardware configuration.

Short strategy description for navigation and applications
The RGB-D point cloud is processed to detect and follow crop rows with a custom controller. End-of-row turning is performed combining custom mapping, gmapping and move_base. Waste and weeds are detected with a Convolutional Neural Network (CNN) and localized through Simultaneous Localization and Mapping (SLAM). Additional RGB-D cameras detect and localize the reference pillars.

These are the commercial team sponsors & partners
-

4. HELIOS evo

Team members:	David Bernzen, Enrico Schleef, Johann Thölking, Marc Schernus, Steffen Lohmann, Tobias Lamping		
Team captain:	Tobias Lamping		
Instructor(s):	Dr.-Ing. Jan Schattenberg		
Institution:	Technische Universität Braunschweig		
Department:	Institut für mobile Maschinen und Nutzfahrzeuge		
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Street / Number:	Langer Kamp 19a	ZIP Code:	38106
Email:	info@fredt.de		
Webpage:	www.fredt.de		

THE MACHINE			
W x L x H (cm):	35 x 69 x 40	Weight (kg):	25
Commercial or prototype:	Prototype	Number of wheels:	4/4
Drivetrain concept / max. speed (m/s):	4WD / 3,5	Turning radius (cm):	75
Battery type / capacity (Ah):	4500 mAh	Total motor power (W):	250
Sensor(s) type(s) used:	2x LIDAR: SICK TIM 571 Odometry Unit Camera: 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.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 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 is another micro-controller (ESP-WROOM-32) which is 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 task two the goal is to detect as many weeds and beer cans as possible and signal them acoustically. Furthermore, in the real field, the robot should bring the cans outside the crop area on the headland.

These are the commercial team sponsors & partners (if there are)
Technische Universität Braunschweig; INSTITUT FÜR mobile Maschinen und Nutzfahrzeuge

5. Robatic group / Steketee Bullseye

Team members:	Joost Koolen, Derek te Bokkel, Stefan Jannink, Etienne Pors and Thijmen Ros		
Team captain:	Etienne Pors		
Instructor(s):	Sam Blaauw and Rick van Essen		
Institution:	Wageningen University and Research		
Department:	Farm Technology Group		
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Street / Number:	Droevendaalsesteeg 1	ZIP Code:	6708 PB
Email:	Robatic.bullseye@gmail.com		
Webpage:	www.robatic.nl		

THE MACHINE			
W x L x H (cm):	42 x 209 x 51	Weight (kg):	30
Commercial or prototype:	Prototype	Number of wheels:	4/4
Drivetrain concept / max. speed (m/s):	Four-wheel independent drive	Turning radius (cm):	0
Battery type / capacity (Ah):	7000 Ah two batteries at the same time	Total motor power (W):	4 * 150 = 600
Sensor(s) type(s) used:	1 LIDAR scanner, 1 IMU and a camera for detection		

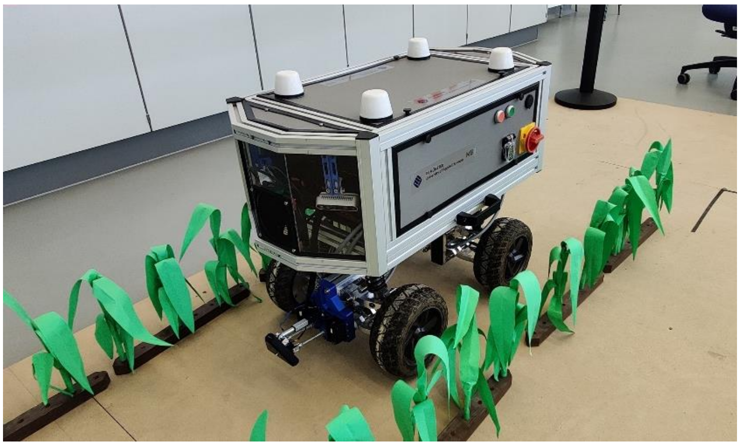
Controller system software description (sensor data analysis, machine control etc.)
ROS1

Controller system hardware description (motor controller, computer etc.)
The computer has the CPU intel I7-4770T, the motherboard is a MIS Z87I, the SSD is a SanDisk SSD 120GB and the RAM is a Corsair Vengeance DDR3 1600 MHz 2x4GB. The driving motor controllers are EPOS 24/5 Motor Controllers. The steering motor controllers are Solutions CubedMotionMind Rev2 An Arduino nano is used for the emergency brake/stop

Short strategy description for navigation and applications
We navigate by LIDAR sensor.

These are the commercial team sponsors & partners (if there are)
Steketee Claas Stiftung LA architecten & ingenieurs Agrifac Machinery Kverneland Group Livestock Robotics

6. FH Münster / CERES II



Team members:	Constantin Eckes, Marc Philipp Funcke, Natalie Peracha, Jannis Wagner		
Team captain:	Marc Philipp Funcke		
Instructor(s):	Jochen Korn, Matthias Nießing		
Institution:	FH Münster University of Applied Sciences		
Department:	Department of Mechanical Engineering		
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Email:	marc.funcke@fh-muenster.de		
Webpage:	www.fh-muenster.de/maschinenbau/labore/agrarroboter/agrarroboter.php		

THE MACHINE			
W x L x H (cm):	45 x 82 x 60	Weight (kg):	60
Commercial or prototype:	Prototype	Number of wheels:	4 / 4
Drivetrain concept / max. speed (m/s):	Four wheel steering / 4	Turning radius (cm):	45
Battery type / capacity (Ah):	LiIon 7S 24,15Ah	Total motor power (W):	4 x 250 = 1000
Sensor(s) type(s) used:	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 Melodic, 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. 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 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

7. FLORIBOT

Team members:	Michael Ball, Benedict Bauer, Moritz Böker, Philipp Kugler, Jonathan Müller, Patrick Stutz		
Team captain:	Benedict Bauer		
Instructor(s):	Torsten Heverhagen		
Institution:	Heilbronn University of Applied Sciences		
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Webpage:	www.hs-heilbronn.de/floribot		

THE MACHINE			
W x L x H (cm):	43 x 132 x 45	Weight (kg):	60
Commercial or prototype:	Prototype	Number of wheels:	4/4
Drivetrain concept / max. speed (m/s):	All-wheel drive articulated steering / 2	Turning radius (cm):	37,5
Battery type / capacity (Ah):	Stiga SBT 5048 AE 2 x 5 Ah	Total motor power (W):	4 x 300
Sensor(s) type(s) used:	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.)
Nvidia Jetson AGX Xavier, Raspberry Pi 4B, SEW DHE41B and SEW CMP ELVCD

Short strategy description for navigation and applications
The navigation in rows is based on a simple algorithm, which uses the position of the robot relative to the middle of the rows to determinate it’s speed and steering angle. The position of the robot relative to the middle of the rows is determinated by the use of box filters. 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

8. Acorn

Team members:	Simon Balzer; Janosch Bajorath; Lena Brüggemann; Tim Buschermöhle; Christopher Sieh; Leon Rabius; Max Hattenbach; Lara Lüking; Marcel Flottmann; Celina Müller; Paul Hermann		
Team captain:	Frederik Schierbaum		
Instructor(s):	Thomas Wiemann, Alexander Mock, Matthias Igelbrink		
Institution:	University Osnabrück, University of Applied Sciences Osnabrück.		
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Webpage:	-		

THE MACHINE			
W x L x H (cm):	40 x 86 x 46	Weight (kg):	32
Commercial or prototype:	Prototype	Number of wheels:	4 /4 WD
Drivetrain concept / max. speed (m/s):	Differential Drive / 1,42	Turning radius (cm):	0
Battery type / capacity (Ah):	36V/6Ah 18V/5Ah	Total motor power (W):	4 x 100
Sensor(s) type(s) used:	5/6 Wheelrotation sensors, IMU, 3D-Sensor, 2D-Sensor, Cameras		

Controller system software description (sensor data analysis, machine control etc.)
The sensors publish their data over ethernet or USB to the main PC which computes the behaviour of the robot. The whole system is based around ROS melodic, running on Ubuntu 18.04. The recognition of the objects (Weed, cans) is done by a neuronal network on a Jetson. The used data comes from the cameras. The drilling application is connected via ROS from a Raspberry PI

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. For object detection we are using intel real-sense cameras which send their data to a Jetson. For navigation we use the main PC, a Pokini I2, with the intrinsic sensors as well as the 2D and the 3D sensor. The drilling application we use in the freestyle task comes with a Raspberry PI and is mounted on the back of our robot. It uses a motor for the drill and another one for the hatch.

Short strategy description for navigation and applications
Our robot detects the maize rows via the 2-D and 3-D sensor and organizes the measured data in multiple matrices. With these matrices it discerns where the rows are relative to the robot. Inside the rows we estimate the course of the rows. Outside of the rows we count the number of rows passed and drive with that knowledge to the start of the next needed row.

These are the commercial team sponsors & partners (if there are)
Amazone, SICK, IOTEC

9. ATH Rover

Team members:	Lukas Nagelmann, Jessica Emminghaus, Nathanael Ebertshäuser, Paul Speitelsbach, Yannik Brunotte		
Team captain:	Nathanael Ebertshäuser		
Instructor(s):	David Reiser, Nils Lüling		
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Webpage:	-		

THE MACHINE			
W x L x H (cm):	80 x 40 x 35	Weight (kg):	25
Commercial or prototype:	Prototype	Number of wheels:	4 / 4
Drivetrain concept / max. speed (m/s):	Electric drive / 1.5	Turning radius (cm):	0
Battery type / capacity (Ah):	Li-Ion / 13 Ah	Total motor power (W):	800
Sensor(s) type(s) used:	4 / 1: Odometry, LIDAR		

Controller system software description (sensor data analysis, machine control etc.)
CAN Open, ROS

Controller system hardware description (motor controller, computer etc.)
CAN Open, Tablet

Short strategy description for navigation and applications
ATH Rover navigates through point clouds. While maize plants are detected, it will drive forward between them. When there are no more maize plants, the mode is changed. The wheels will turn 90 degrees, then it will drive the length of the row spacing, turn again and drive backwards between the next rows.

The sensing and mapping task will build on the navigation. If a weed or garbage is detected, the position is calculated. In our freestyle task, we will sense soil moisture and temperature at specific points. After that, our robot is going to seed.

These are the commercial team sponsors & partners (if there are)
CLAAS Stiftung RAUCH

10. FarmBeast

Team members:	Urban Kenda, Rok Friš, Miha Kajbič, Erik Rihter, Gregor Popič, Liza Škulj, Urban Navršnik		
Team captain:	Urban Kenda		
Instructor(s):	Prof. Dr. Miran LAKOTA Dr. Jurij RAKUN		
Institution:	Faculty of Agriculture and Life Sciences, University of Maribor		
Department:	Biosystems engineering		
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Webpage:	www.farmbeast.um.si, www.fkbv.um.si		

THE MACHINE			
W x L x H (cm):	52,7 x 65 x 50	Weight (kg):	55
Commercial or prototype:	Prototype	Number of wheels:	4
Drivetrain concept / max. speed (m/s):	0.5	Turning radius (cm):	75
Battery type / capacity (Ah):	6	Total motor power (W):	800
Sensor(s) type(s) used:	Velodyne VLP-16 multichannel LIDAR ||SICK TIM310 LIDAR sensor,2 x camera, IMU		

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.

11. Camper Robotics / RON

Team members:	Erwin Kose, Fabian Paul, Isaak Körner, Konstantin Grebhahn		
Team captain:	Simon Sure		
Instructor(s):	-		
Institution:	Private project group		
Department:	-		
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Webpage:	https://field-robot.net		

THE MACHINE			
W x L x H (cm):	38 x 60 x 33	Weight (kg):	18
Commercial or prototype:	Prototype	Number of wheels:	4 / 4
Drivetrain concept / max. speed (m/s):	4 WD / 4	Turning radius (cm):	0
Battery type / capacity (Ah):	Li-Ion / 36 V, 4,4	Total motor power (W):	1400
Sensor(s) type(s) used:	Internal: - IMU (1x for odometry) - Hall motor sensors (1x per motor) External: - 4 cameras (resolution 640x480, only used at about a sixteenth of the resolution for navigation)		

Controller system software description (sensor data analysis, machine control etc.)
We utilize the second-generation Robot Operating System (ROS2). First, using basic computing, transform and odometry information is generated by using the motor hall sensors, IMU and cameras. The sensor processing pipeline starts with a fully connected convolutional AI analysis of all four

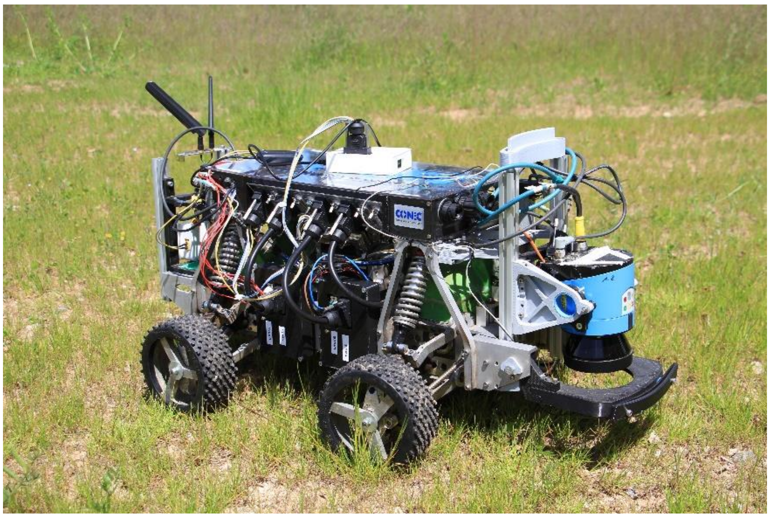
rectified camera signals. The AI identifies drivable space on images. After an inverted image projection, the generated point clouds for each camera are (a) used separately and (b) fused for certain navigation and mapping purposes. The mapping and navigation software utilizes the mentioned point clouds, odometry and transform information. Drive commands are sent to the motor controller, which moves the motors accordingly. It is possible to either use a PID controller for the four wheeled robot used in the competition, or a sophisticated algorithm for the self-balancing version.

Controller system hardware description (motor controller, computer etc.)
The robot operates using to separate Nvidia Jetson Nano Developer Boards for flexibility and scalability. Both boards are connected via a local network interface. The cameras and one IMU are directly connected to the Jetson computers. Both run Ubuntu with ROS2 and enable graphic accelerated AI inference. Motor commands are sent via a serial connection to the motor controller (a reused Hoverboard motor controller). It provides power to the motors. One battery is directly connected to the motor controller. A different power circuit is used to power both Nvidia Jetsons.

Short strategy description for navigation and applications
Navigation is based on the modular Navigation2 package. It uses the point clouds and a goal point for navigation. The point clouds have already been filtered for plant gaps during the above-mentioned AI inference. While driving in a row, a plausible goal point can be determined by using the regularly updated mean of the front camera point cloud and the inverted mean of the back camera point cloud. Thus, the first part of the planed route can always be used. During headland turns, an estimate for the target row’s entrance point is set as the goal point. When doing a multi row headland turn, this point is updated according to the availability of new information.

These are the commercial team sponsors & partners (if there are)
This project has been financially supported by the German Youth Science Competition’s sponsor pool.

12. Kamaro Engineering e.V.



Team members:	Johannes Barthel, Johannes Bier, Kai Baumgardt, Edvardas Bulovas, Kevin Daiß, Fabian Duttlinger, Robin Eistetter, Thomas Friedel, Stephan Göhner, Tobias Hintz, Aysun Hyudain, Michael Keppler, Mathias Krohmer, Jonas Lewandrowski, Michael Liu, Konstantin Lutz, David Mall, Olivia Mammadova, Maik Mszyca, Karolina Polnik, Lea Schulze, Olivia Schwertfeger, Tim Sentler, Leon Tuschla, Erik Wurstmann, Philip Ziser		
Team captain:	Johannes Bier		
Instructor(s):	Electronics: Stephan Göhner Mechanics: Fabian Duttlinger Software: Johannes Bier Organization: Kamaro Engineering e.V.		
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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):	40
Commercial or prototype:	Prototype	Number of wheels:	4/4
Drivetrain concept / max. speed (m/s):	4-Wheeldrive / 2	Turning radius (cm):	50
Battery type / capacity (Ah):	6 cell LiPo/ 10	Total motor power (W):	220
Sensor(s) type(s) used:	LIDAR SICK LMS100, 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 corn plants. For the weeding task, we use a camera for detecting the litter and weeds on the field. As our Freestyle task we are planning to present the advantages of our newly implemented BUS-Systems, which allows for a quick and easy installation of new modules.

These are the commercial team sponsors & partners (if there are)
Companies: SICK, Dunkermotoren, Schaeffler, Nozag, Igus, CONEC, Pepperl+Fuchs, Ganter Griff, Eurocircuits, ViGEM Institutes at the KIT: MOBIMA/FAST, WBK

June 14th to 16th, 2022

Monday, June 13th

Registration of teams

16:00 – 17:00 Briefing of team captains (not public)

Tuesday, June 14th

09:00 – 10:00 Welcome note

Task Navigation

Basic and advanced navigation in a maize field
(max travelled distance per time will win)

10:00 – 12:00 **Simulation Contest**

14:00 – 16:00 **Field Contest**

16:30 – 17:00 **Awarding**

17:00 – 17:30 FAQ and support (not public)

Wednesday, June 15th

Task Sensing, Mapping & Removal

Weed and object detection, georeferencing in a maize field
(correct map & can removal will win)

10:00 – 12:00 **Simulation Contest**

14:00 – 16:00 **Field Contest**

16:30 – 17:00 **Awarding**

17:00 – 17:30 FAQ and support (not public)

Thursday, June 16th

Task Freestyle

Free Style: Free choice for the teams
(Complexity, performance and usefulness will win)

10:00 – 11:00 **Simulation Contest**

12:00 – 13:00 **Field Contest**

13:30 – 14:30 **Awarding**

Farewell

LEMKEN
The Agrovision Company

K.U.L.T.
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FENDT

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