HEILBRONN UNIVERSITY
OF APPLIED SCIENCES

FIELD ROBOT EVENT 2019 BOOKLET

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Acknowledgements

Thanks to all who contributed to the organisation!

HEILBRONN UNIVERSITY
OF APPLIED SCIENCES

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Sponsors

We thank all the **sponsors** for their contribution and
their simple and generous support.

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

Welcome to the Field Robot Event 2019!

The 17th Field Robot Event (FRE) will take place in Heilbronn, Germany, from June 17th to 21st 2019. The FRE 2019 is held in conjunction with the BUGA 2019 (Bundesgartenschau), a national outdoor gardening exhibition organized by the BUGA.

The FRE has been founded by the Wageningen University in 2003 in order to motivate students to develop autonomous field robots. The agricultural tasks will be challenging for the robots and their students behind them, but beside engineering skills we want to promote meeting international colleagues for exchanging expertise & experience but also having fun during the contest!

The international Field Robot Event is an annual outdoor contest on an agricultural field, where students and their supervisors compete within several tasks in autonomous navigation and other operations. In 2019 the contest again will be different compared to last years. During the two application tasks in weed control the solutions are expected to be complex & challenging and hence more realistic. Furthermore, in 2019 there will be again a Robot Design Award awarded by the international jury.

We wish all teams to have good ideas for solving problems (challenges!), good success in implementation and fun & good luck!

On behalf of the organising team

Torsten Heverhagen

You find more information on the internet: http://www.fieldrobot.com/event/

Program

June 17th to 21st 2019

Monday, June 17th

14:00 – 18:00 Arrival and team registration (all day)
14:00 – 18:00 First testing in the test fields
18:00-19:00 Joint dinner

Tuesday, June 18th

09:00 – 18:00 Arrival and team registration (all day)
09:00 – 18:00 Testing in the test fields
14:00 – 16:00 Team registration, presenting the teams & robot testing
17:00 – 18:00 Briefing of team captains
18:00-19:00 Joint dinner

Wednesday, June 19th

09:00 – 10:00 Testing in the test fields
10:00 – 10:30 Welcome note
10:30 – 12:30 **Contest Task 1 (basic navigation)**
14:00 – 16:00 **Contest Task 2 (advanced navigation)** & awarding
18:00-19:00 Joint dinner

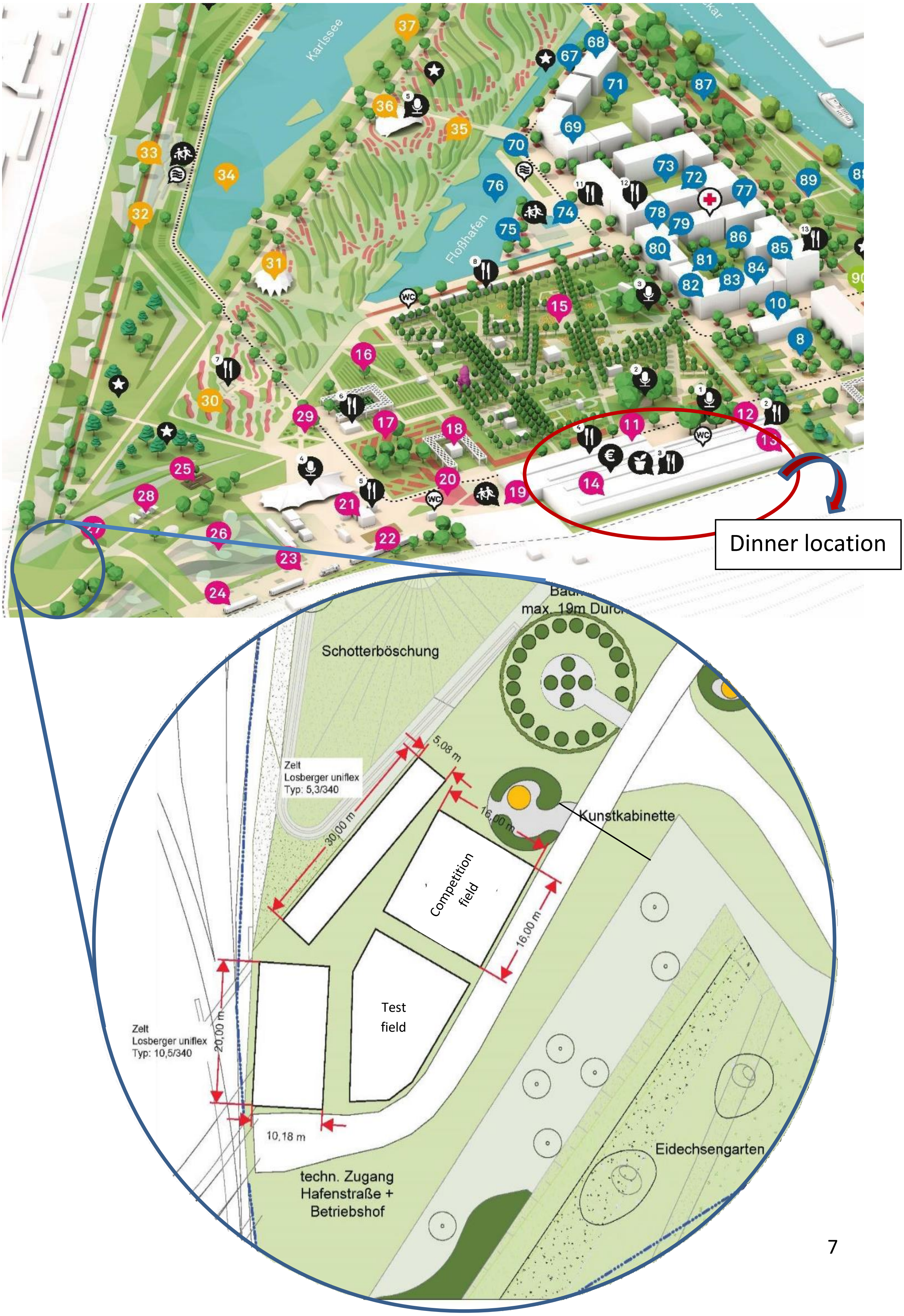
Thursday, June 20th

09:00 – 10:00 Briefing of team captains
10:00 – 12:00 **Contest Task 3 (field mapping)**
14:00 – 16:00 **Contest Task 4 (weeding)** & awarding
18:00 – 22:00 Final contest awarding (and joint dinner)

Friday, June 21st

09:00 – 10:00 Robot testing
10:00 – 11:30 **Contest Task 5 (free style)**
11:30 – 12:00 Awarding Task 5
Farewell

Competition Area and BUGA



Field Robot Event 2019 - Task Description

Together with the BUGA (Bundesgartenschau), 17th – 21st June 2019
Heilbronn, 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.

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 with unallowed 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 connections to a participating team. All relevant communication will be in English. To please national spectators, the contest moderation could partly switch to a national language.

In 2019 five tasks will be prepared to challenge different abilities of the robots in terms of sensing, navigation and actuation: Basic Navigation, Advanced Navigation, Sensing, Weeding Control and Free Style (option).

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

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.

During the machine runs for each task no team members are 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 can then 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.

0.1. General rules

The use of a GNSS receiver is not allowed except for the Free Style in Task 5[1]. The focus for the other tasks in terms of localization shall be on relative positioning and sensor-based behaviours.

Crop plants

[1] If you wish to use a GNSS, you will have to bring your own.

The crop plants in tasks 1 to 4 are maize (corn) or *Zea Mays*[2]. The maize plants will have a height of approximately 20 - 40 cm. The general appearance of the crop plants are location specific as well as yearly specific.

Damaged plants

A damaged plant is a maize plant that is permanently bent, broken or uprooted. The decision that a maize plant is damaged by a machine or not will be made by the jury members.

Parc fermé

During the contests, all robots have to wait in the parc fermé and no more machine modification to change the machine performance is allowed 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 to 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 each run.

0.2. General requirements for all robots

Autonomous mode

All robots must act autonomously in all tasks, including the freestyle. Driving by any remote controller during the task 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 are 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 at 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 be brought back into the parc fermé after a basic repair as soon as possible. If the robot fails twice, the robot will be excluded from the task 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. 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 colours.

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

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.

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.

While the robot is STOPPED and one team member is allowed to be in the field, besides rotating the robot, the team member is allowed to touch the buttons and other input devices mounted on the robot. Other remote controllers besides START/STOP controller are strictly prohibited to be used at any time.

Implementation note: If using Logitech Cordless Gamepad or equivalent as a remote controller, the recommended practice is to paint/tape 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 potential 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 within the row, where the robot may need to get back to the path if a wheel or track of the robot has collided a 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.

In the headland, only rotating to give the robot a new orientation is allowed, no moving or even carrying is allowed at all.

0.3. Awards

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, especially in task 4 and task 5 (freestyle), will be evaluated. There will be an award for the first three ranks of each task. The basic navigation (1), advanced navigation (2), sensing (3), and weeding (4) together will yield the overall competition winner. 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 four tasks (1, 2, 3 and 4) will be ranked higher.

1. Task "Basic navigation" (1)

1.1. General description

For this task, the robots are navigating autonomously. Within three minutes, the robot has to navigate through long curved rows of maize plants (*picture 1* at the end of this text). The aim is to cover as much distance as possible. On the headland, the robot has to turn and return in the adjacent row. There will be no plants missing in the rows. This task is all about accuracy, smoothness and speed of the navigation operation between the rows.

At the beginning of the match it will be told whether starting is on the left side of the field (first turn is right) or on the right side (first turn is left). This is not a choice of the team but of the officials. Therefore, the robots should be able to perform for both options. A headland width of 2 meters free of obstacles (bare soil) will be available for turning.

1.2. Field Conditions

Random stones are placed along the path to represent a realistic field scenario. The stones are not exceeding 25 mm from the average ground level. The stones may be small pebbles (diameter <25 mm) laid in the ground and large rocks that push (max 25 mm) out from the ground, both are installed. In other words, abilities as defined by machine ground clearance and to climb over small obstacles are required.

A red 50 mm wide textile tape is laid in the field 2 m from the plants.

1.3. Rules for robots

For starting, the robot is placed at the beginning of the first row without exceeding the white line.

If the robot is about to deviate out from the path and hit maize plants, the team member with the remote controller must press the STOP button immediately. The STOP button must be pressed before the robot damages stems of the maize plants. The team is responsible to monitor the behavior of the robot and to use the STOP button when necessary.

1.4. Assessment

The distance travelled in 3 minutes is measured. The final distance will be calculated including a special 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:

Final distance = corrected distance * 3 minutes / measured time.

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 1 meter per plant.

The task completing teams will be ranked by the results of resulting total distance values. The best 3 teams will be rewarded. This task 1, together with tasks 2, 3 and 4, contribute to the overall contest winner 2019. Points for the overall winner will be given as described under chapter 0.3 Awards.

2. Task “Advanced navigation” (2)

2.1. General description

For this task, the robots are navigating autonomously. Under real field conditions, crop plant growth is not uniform. Furthermore, sometimes the crop rows are not even parallel. We will approach these field conditions in the second task.

The rules for entering the field, moving the robot, using remote controller etc. are the same as in task 1.

No large obstacles in the field, but more challenging terrain in comparison to task 1.

The robots shall achieve as much distance as possible within 3 minutes while navigating between rows of maize plants, but the robots have to follow a certain predefined path pattern across the field (*picture 2* at the end of this text). Additionally, at some locations, plants will be missing (gaps) at either one or both sides with a maximum length of 1 meter. There will be no gaps in row entries.

The robot must drive the paths in given order. The code of the path pattern through the maize field is done as follows: S means START, L means LEFT hand turn, R means RIGHT hand turn and F means FINISH. The number before the L or R represents the row that has to be entered after the turn. Therefore, 2L means: Enter the second row after a left-hand turn, 3R means: Enter the third row after a right hand turn. The code for a path pattern, for example, may be given as: S - 3L - 2L - 2R - 1R - 5L - F.

The code of the path pattern is made available to the competitors 15 minutes before putting all robots into the parc fermé. Therefore, the teams will not get the opportunity to test it in the contest field.

2.2. Field conditions

Random stones are placed along the path, to represent realistic field scenario where the robot should cope with holes etc. The stones are not exceeding the level of 35 mm from the average ground level in the neighborhood. The stones may be pebbles (diameter

<35 mm) laid in the ground and large rocks that push (max 35 mm) out from the ground, both are installed. In other words, the robot must have ground clearance of this amplitude at minimum, and the robot must be able to climb over obstacles of max 35 mm high. No maize plants are intentionally missing at the end of the rows. However, due to circumstances of previous runs by other robots, it is possible that some plants at the end of the rows are damaged. The ends of the rows may not be in the same line, the maximum angle in the headland is ±15 degrees.

No large obstacles in the field and all rows are equally passable. A red 50 mm wide textile tape is laid in the field 2 m from the plants.

2.3. Assessment

The distance travelled in 3 minutes is measured. The final distance will be calculated including a special 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:

Final distance = corrected distance * 3 minutes / measured time.

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 1 meter per plant. In the case that a robot must be stopped manually after leaving a row, it will have to be placed within the row, which the robot was leaving before.

The task completing teams will be ranked by the results of resulting total distance values. The best 3 teams will be rewarded. This task 2, together with tasks 1, 3 and 4, contribute to the overall contest winner 2019. Points for the overall winner will be given as described under chapter 0.3 Awards.

Picture 2 shows an example of how the crop rows and the path tracks could look like for task 2. Be aware, the row gaps and the path pattern will be different during the contest!

3. Task “Field Mapping” (3)

3.1. General description

For this task, the robots are navigating autonomously. The robots shall detect weed patches represented by pink golf balls and obstacles represented by yellow tennis balls. You can find further details regarding the tees at the end of this document (Appendix B). Task 3 is conducted on the area used in task 2 with straight rows. The map created in this task will be used in task 4. Up to ten obstacles may be placed in the field, either between rows or in the headland. Obstacles must not be passed regardless of whether the robot can do so without touching them. Up to ten weeds may be placed in the field. All weeds will be placed between rows.

The rules for entering the field, moving the robot, using remote controller etc. are the same as in task 1 and task 2.

3.2. Field conditions

As in task 2 random stones are placed along the path, to represent realistic field scenario, where the robot should cope with holes etc. The stones are not exceeding the level of 35 mm from the average ground level in the neighbourhood. The stones may be pebbles (diameter <35mm) laid in the ground and large rocks that push (max 35 mm) out from the ground, both are installed. In other words, the robot must have ground clearance of this amplitude at minimum, and the robot must be able to climb over obstacles of max 35mm high. No maize plants are intentionally missing in the end of the rows. However, due to circumstances of previous runs by other robots, it is possible that some plants in the end of the rows are damaged.

The weeds are objects represented by pink golf balls randomly distributed between the rows in the soil so that only the upper half is visible. Robots may drive across or over them without a penalty. The weeds are located in a band 60 cm wide between the rows. No weeds are located within rows or on headlands.

Obstacles are represented by yellow tennis balls, which will be placed randomly between rows and on the headland. Robots are not permitted to touch or pass the obstacles.

3.3. Rules for robots

Each team has only one attempt. The maximum available time for the run is 5 minutes.

Points will be awarded for detecting weeds and obstacles and for recording their positions. The positions must be given in a Cartesian coordinate system with its origin and orientation equal to the starting pose of the robot. The positions (the map) must be provided in a text file similar to the one in picture 5.

Teams can nominate whether they wish to indicate the detection of weeds and obstacles separately from the mapping of their locations using audible or visual signals. Once the nomination has been made then that method must be used for the task. By using audible or visual signals it is possible to get points for the detection of weeds and obstacles even if a map is wrong or missing.

There is no requirement for the robot to travel along every row, provided that all obstacles and weeds are detected, i.e. it is acceptable for example to have a robot with a high mounted camera which is capable of surveying two or three rows at a time.

A single robot navigates between the rows, as in tasks 1 and 2, giving an audible signal when it comes across each weed or obstacle to indicate that it has detected it at that location. The detection of a weed should be indicated by a two second signal and the detection of an obstacle should be indicated by a five second signal. A robot that is capable of surveying more than one row at a time must indicate the row in which it has detected the obstacle or weed.

A robot producing an acoustic signal without any reason will be regarded as a false positive. Failure to produce an acoustic signal when an obstacle or weed is encountered will be regarded as a false negative.

The robot should have some means of storing the locations of the weeds and obstacles as this information will be required to complete task 4.

3.4. Assessment

Each correctly identified and located weed or obstacle (true positives) will be awarded according to the following:

audible or visible signaling without correct mapping	audible or visible signaling with correct mapping	correct mapping without audible or visible signaling
4 point	6 points	6 points

A correct mapping is given, if the recorded location is within a square meter, which is centered in the true location. So the tolerance for x, y is +/- 0.5m.

Crop plant damage by the robot will result in a penalty of 2 points per plant. Passing obstacles will result in a penalty of 5 points per obstacle.

Manual intervention to move or adjust the robot will result in a penalty of 2 points for each time the robot is STOPPED.

Indicating the presence of a weed or obstacle when none is present in that location (false positives) will result in a penalty of 1 point per occurrence.

Failure to indicate the presence of a weed or obstacle when one is present (false negatives) will result in a penalty of 2 points per occurrence.

The Jury will register the number of true positives, false positives and false negatives:

The total travelled distance will not be assessed.

If a team completes the task in less than 5 minutes (excluding the 2 minutes allowed to produce a map), this time will be used to calculate a bonus factor = total points x 5minutes/measured time.

The task completing teams will be ranked by the number of points as described above.

The three best teams will be rewarded.

4. Task "Weeding" (4)

4.1. General description

In this task the main robot should be equipped with a crop sprayer capable of spraying water.

The robot may use the map created in task 3 to produce an optimised path that allows it to spray all of the weeds in the shortest possible time. Teams will be allowed 10 minutes to configure their robot for spraying and load an optimised path into its navigation system. The path optimisation process can be completed using a computer that is independent of the main robot, but this process must be completed within the 10 minute time window.

Alternatively, the robot may go without a map or an optimized path. Without an optimized path, it is more difficult to complete the task within 3 minutes.

The robots shall precisely spray the weeds mapped in task 3. It is not permitted to touch or pass the yellow tennis balls.

4.2. Field conditions

As in task 2 and 3 random stones are placed along the path, to represent realistic field scenario where the robot should cope with holes etc. The stones are not exceeding the level of 35 mm from the average ground level in the neighbourhood. The stones may be pebbles (diameter <35mm) laid in the ground and large rocks that push (max 35 mm) out from the ground, both are installed. In other words, the robot must have ground clearance of this amplitude at minimum, and the robot must be able to climb over obstacles of max 35mm high. No maize plants are intentionally missing in the end of the rows. However, due to circumstances of previous runs by other robots, it is possible that some plants in the end of the rows are damaged.

The weeds are objects represented by pink golf balls randomly distributed between the rows in the soil that only the upper half is visible. Robots may drive across or over them without a penalty. The weeds are located in a centred band of 60 cm width between the rows. No weeds are located within rows and on headlands.

Obstacles are represented by yellow tennis balls which will be placed randomly between rows and on the headland. Robots are not permitted to touch or pass the obstacles.

The location of the obstacles and weeds will be the same in tasks 3 and 4.

As in task 3, there is no requirement for the robot to drive along every row, provided all weeds are sprayed.

4.3. Rules for robots

Each robot has only one attempt. The maximum available time for the run is 3 minutes.

The robot must give an audible signal when the sprayer is operated.

The robot must spray only the weeds or the circular area around the golf ball with a diameter of 25 cm. Spraying outside this weed circle is counted as false positive, with no true positive scoring.

In the case that the robot is spraying or producing an acoustic signal without any reason, this is regarded as false positive.

Failure to spray a weed one is present (false negatives) will result in a penalty of 2 points per occurrence.

4.4. Assessment

Crop plant damage by the robot will result in a penalty of 2 points per plant.

Manual intervention to move or adjust the robot will result in a penalty of 2 points for each time the robot is STOPPED.

Activating the sprayer or making an audible signal when no weed is present in that location (false positives) will result in a penalty of 1 point per occurrence.

Failure to spray a weed when one is present (false negatives) will result in a penalty of 2 points per occurrence.

The Jury will register the number of true positives, false positives and false negatives:

Each time a weed is sprayed correctly with the appropriate audible signal (true positives) 6 points will be awarded.

If a weed is sprayed correctly but without an audible signal 4 points will be awarded.

The total travelled distance will not be assessed.

If a team completes the task in less than 3 minutes, this time will be used to calculate a

bonus factor = total points x 3minutes/measured time.

The task completing teams will be ranked by the number of points as described above.

The three best teams will be rewarded.

5. Task “Freestyle” (5)

5.1. Description

Teams are invited to let their robots perform a freestyle operation. Creativity and fun are required for this task as well as an application-oriented performance. One team member has to present the idea, the realization and perhaps to comment the robot’s performance to the jury and the audience. 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.

5.2. Assessment

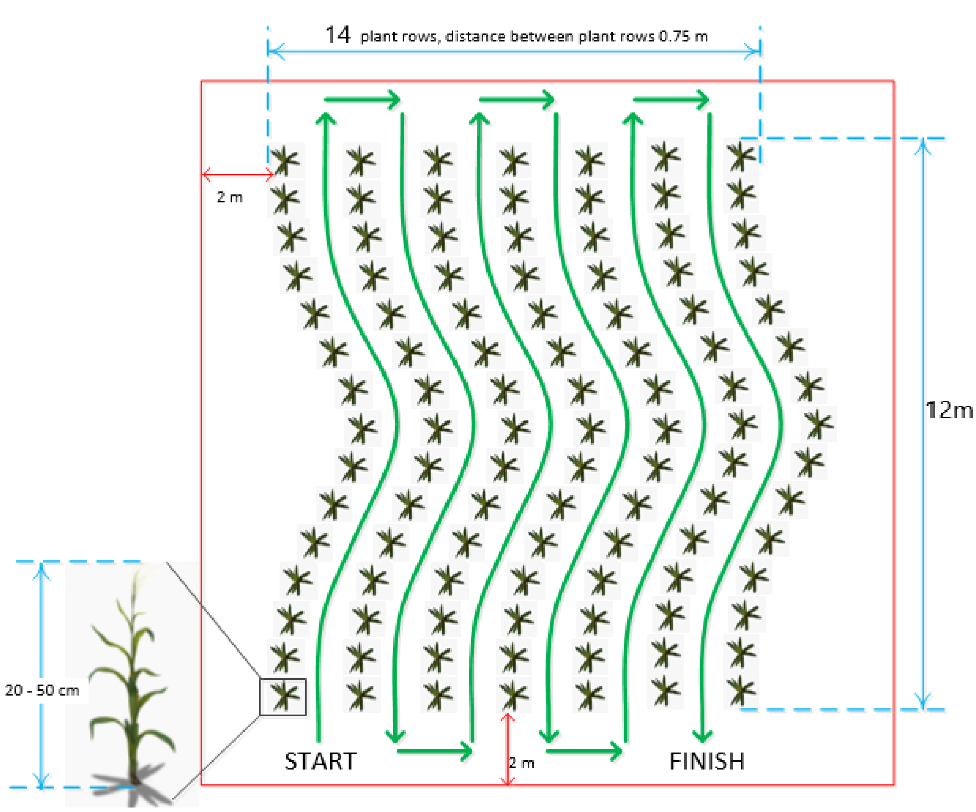
The jury will assess the (i) agronomic idea, the (ii) technical complexity and the (iii) robot performance by giving points from 0 (insufficient) to 10 (excellent) for each.

The total points will be calculated using the following formula:

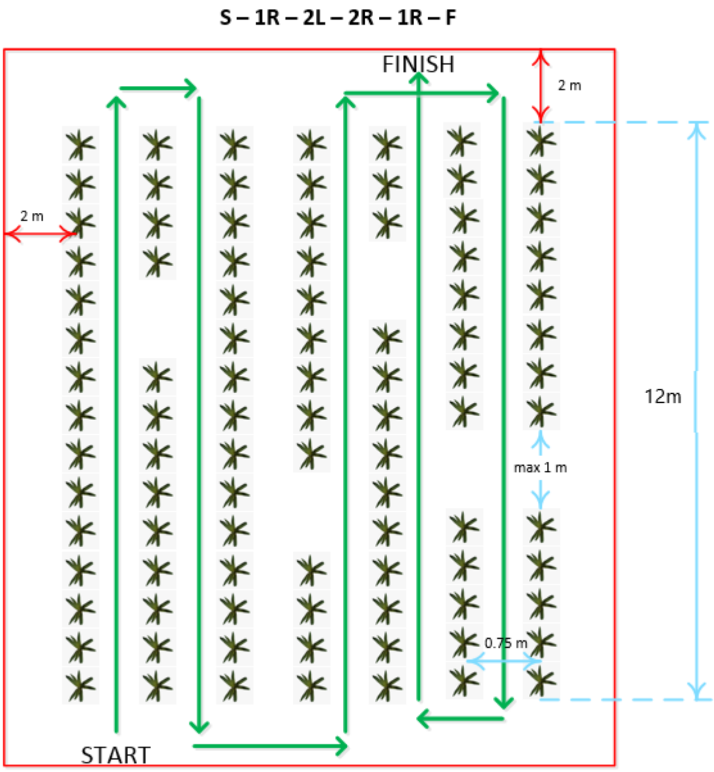
Final points = (agronomic idea + technical complexity) * performance.

Task 5 is optional and will be awarded separately. It will not contribute to the contest winner 2019.

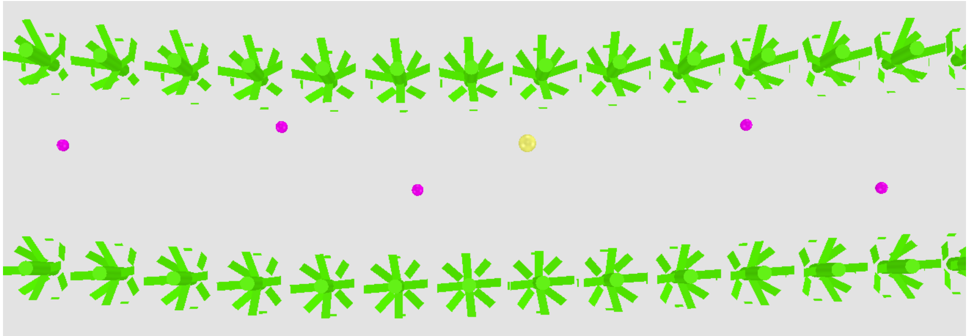
Appendix A



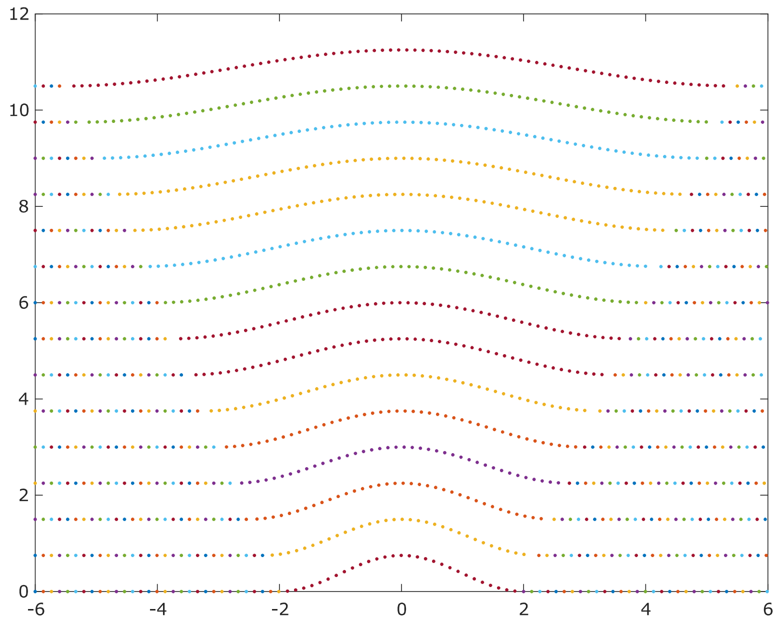
Picture 1 – Dimensions and row pattern for task 1.



Picture 2 – Dimensions and example (!) of row navigation pattern for task 2.



Picture 3 – Possible locations of the weeds and obstacles for task 3 and task 4.



Picture 4 – This is the actual layout of the row pattern. So there are no straight lines this year.

X	Y	Kind
2.6	3.5	weed
3.8	3.5	weed
4.8	3.5	obstacle

Picture 5 – Example for a map file, recorded in Task 3

P 2018.04.16

Participating Teams

1. Banat Robot

"Banat"

THE TEAM			
Names of team members:	Eliza Crișan, Cornel Tureac, Darius Nagy, Adrian Țucudean, Andrei Mătrăgună, Cătălin Almășan		
Name team captain:	Eliza Crișan		
Instructor(s):	Sorin Nanu, Sorin Bungescu		
Institution:	"Politehnica" University and Banat University of Agricultural Sciences and Veterinary Medicine Timișoara		
Department:	Automation and Applied Informatics and Machinery and Equipment for Agriculture and Food Industry		
Country:	Romania	City:	Timișoara
Street / Number:	Calea Aradului nr. 119	ZIP Code:	300643
Email:	eliza.crisan@gmail.com / sobungi@yahoo.com		
Webpage:	-		

THE MACHINE			
W x L x H (cm):	30 x 50 x 60	Weight (kg):	10
Commercial or prototype:	Prototype	Total no. of wheels / no. driven wheels:	4
Drivetrain concept / max. speed (m/s):	1.5m/s	Turning radius (cm):	0
Battery type / capacity (Ah):	2 Li-Ion + 1 NiMh batteries	Total motor power (W):	2x80(160)
No. sensors internal/ external: Sensor(s) type(s):	3 Lidar, Compass, RaspiCam		

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

Tasks 1 and 2:

- Position and orientation relative to the plants is controlled by LIDAR running a python script on a Raspberry Pi controller
- Orientation and speed are controlled by a PID regulator on an ATMega2560 controller based on direct acquisition of global orientation from the compass and the information received via Serial from the Raspberry Pi
- Certain precision is assured by the camera with object detection

Tasks 3 and 4:

- Image processing is realized using RaspiCam.
- The direction is maintained using the mechanism mentioned above

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

The system contains two controllers: an ATMega2560 used for orientation and speed control and a Raspberry Pi B+ that decides the angle of the robot's direction and also controls the camera used for image recognition. The global orientation regulator uses an HM55B Hitachi compass and the remote control of the robot is assured through an HC-05 Bluetooth adaptor.

Short strategy description for navigation and applications

The robot will navigate the rows holding a steady distance from the plants using the LIDAR and an electronic compass. The LIDAR dictates the new orientation and by reading the compass, the said orientation is achieved very quickly.

The LIDAR will detect the end of the row, the place where the robot needs to turn, and it also counts the rows we pass by. To turn, we use the compass again and after re-entry we switch back to LIDAR.

These are the commercial team sponsors & partners

2. Bullseye

“Bullseye”

THE TEAM			
Names of team members:	Robbin Bloo, Jordy van der Burg, Johan de Groot, Casper van Oostrum, Ruben van der Scheer, Chris Vader		
Name team captain:	Johan de Groot		
Instructor(s):	Ing. Sam Blaauw Thijs Ruigrok		
Institution:	Wageningen University and Research		
Department:	Farm Technology Group (FTE)		
Country:	The Netherlands	City:	Wageningen
Street / Number:	Bornsesteeg 48	ZIP Code:	6708 PB
Email:	robatic.bullseye@gmail.com		
Webpage:	www.robatic.nl		

THE MACHINE			
W x L x H (cm):	44 x 107 * 70	Weight (kg):	35
Commercial or prototype:	Prototype	Total no. of wheels / no. driven wheels:	4/4
Drivetrain concept / max. speed (m/s):	1.3	Turning radius (cm):	28
Battery type / capacity (Ah):	2 * 5.000 mAh	Total motor power (W):	222 Wh
No. sensors internal / external: Sensor(s) type(s):	1 * 2D LiDAR sensor: Sick LMS-111-10100 1 x IMU: Xsens Mti-300 AHRS 1 x Allied Vision camera (Manta G-235C IRC) 4 x Solution CubedMotionMind Rev2 (Steering motor controllers) 4 x Maxon motor EPOS2 24/5 motor controllers (Driving motor controllers)		

Controller system software description (sensor data analysis, machine control etc.)
The software runs in Robot Operating System (ROS) Kinetic on Ubuntu 16.04LTS and is programmed in Python and C++.

Controller system hardware description (motor controller, computer etc.)
Rhe 2D Sick LMS-111 laser scanner data is processed by an MSI Z871 motherboard running an Intel Core i7-4770T processor. To control the 4 independently driven and steered wheels, 4 Maxon Motors are used. EPOS2 controllers are used for propulsion and 4 Motion Mind Rev2 controllers for steering. An additional Arduinos is used to operate the emergency stop. Futhermore, an 8-way relay board is used to control the spraying mechanism. The whole system is powered by two 22.2 V 6S 20C 5000mAh Li-Po batteries.
Short strategy description for navigation and applications
The Maize rows are scanned with the laser scanner fracing forward. With these measurements the robot can holds a certain distance to the rows and thus can navigate between them. Once the robot detects the headland, it starts turning. On the headland, the robot holds distance to the field with the same principle as used in the maizerows. For the detection of the golf- and tennisballs, an Allied Vision camera is used, together with vision sofware. With help of odeometry data, the robot registers the coordinates of the balls. Spraying is done when the ball is detected. The relay board opens the right nozzle.
These are the commercial team sponsors & partners (if there are)
Main sponsor: Steketee Sponsors: Kverneland and possibly more

3. Die Allrounder

"HohBot"

THE TEAM			
Names of team members:	David Reiser, Timo Grupp, Christoph Stumpe, Peter Roth, Jonas Esterl, Florian Kratz, Gedeon Moritz, Jakob Haas, Henning Kuper		
Name team captain:	Timo Grupp		
Instructor(s):	David Reiser		
Institution:	University of Hohenheim		
Department:	Technology in crop production		
Country:	Germany	City:	Stuttgart
Street / Number:	Garbenstr. 9	ZIP Code:	70599
Email:	Henning.kuper@uni-hohenheim.de		
Webpage:	www.uni-hohenheim.de		

THE MACHINE			
W x L x H (cm):	40 x 90 x 65	Weight (kg):	13.1
Commercial or prototype:	prototype	Total no. of wheels / no. driven wheels:	5 / 5
Drivetrain concept / max. speed (m/s):	5,5 m/s	Turning radius (cm):	20 cm
Battery type / capacity (Ah):	Control system battery: Li-Po; 2.2 Ah Gearsystem battery: Li-Po; 5 Ah Battery Tablet:	Total motor power (W):	321,2 W

	Li-Ion; 47 WH		
No. sensors internal / external: Sensor(s) type(s):	3 Camera: GoPro LIDAR: SICK TM571-20101 IMU: Vectornav NV100		

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

Row navigation:

- Read in laserscanner filter rows
- Define row direction and position
- Define goal point
- Use goalpoint to drive to goal
- Start back at point

Headland turn:

- If the rotation angle is too big for normal steering adjustments the fifth wheel drops down
    - Slip reduction
    - More precise turning

Picture analysis:

- Capture and process goPro image (HD) in real-time
    - Gaussian blur
    - HSV filter (different settings for obstacles and wheat)

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

- Control system: Tablet HP Elite x2 1012 G2 with Linux operation system
- 4 gearmotors with encoder for engine; Pololu 37d
- 1 gearmotor for engine o support wheel; modelcraft RB350100-0A101R
- 1 servo motor for support wheel; Multiplex HS 7954SH
- Motor controller; Roboteq SDC2130
- USB-hub as interface
- 5 fan with 5 W

Short strategy description for navigation and applications

Navigation (task 1 & 2):

- Laser scanner scans the plants in the row and creates a point cloud of plants. This point cloud is divided into a right and left row.
- Then a point in the middle of the two lines is calculated and the robot moves towards it.
- Turning process:
- Rear axle loses contact with the ground via the support wheel (Figure 2) with a servo motor.
- This reduces the high friction of the armored steering.
- Robot turns and detects next row.
- Servo motor lifts support wheel again.

Field mapping (task 3):

- robot recognizes the weeds, and the yellow and pink balls via the GoPro
- An acoustic signal is then emitted via a horn.

Weeding (task 4):

- robot recognizes the weeds, and the yellow balls via the GoPro
- A solenoid valve is then actuated and the weeds are sprayed through the nozzles at the front
- A pressure sprayer is used for water supply and pressure.

Freestyle (task 5): Liquid manure piping

- The liquid manure can be applied directly to the plants via a driven hose drum
- The robot pulls a hose behind it through the field
- Then it reverses and the hose is wound up.

These are the commercial team sponsors & partners (if there are)
- CTL Computertechnik - CLAAS Foundation - Mädler

4. Carbonite

“Carbonite”

THE TEAM			
Names of team members:	Hauke Engels; Marcus Bolter; Junus Hirner; Jonas Mayer; Timo Schönegg; Christoffer Raun; Angelique Indlekofer; Taila Keßler; Jacob Schupp		
Name team captain:	Jacob Schupp		
Instructor(s):	Lukas Locher		
Institution:	School		
Department:	Schülerforschungszentrum Südwürttemberg		
Country:	Germany	City:	Überlingen
Street / Number:	Obertorstr. 16	ZIP Code:	88662
Email:	sfz.carbonite@gmail.com		
Webpage:	sfz-bw.de/ueberlingen		

THE MACHINE			
W x L x H (cm):	47 x 71 x 77	Weight (kg):	ca. 16
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. sensors internal / external: Sensor(s) type(s):	2x laserscanner (Sick Tim 571), 1x camera (Jaigo 5000) 1x, Gyrosensor (Pixhawk)		

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

5. ERIC

"ERIC"

THE TEAM			
Names of team members:	Richard Surtees, Chris Gordon and Alan Walker		
Name team captain:	Chris Gordon		
Instructor(s):	Chris Waghorn		
Institution:	Harper Adams University		
Department:	Engineering Department		
Country:	United Kingdom	City:	Newport
Street / Number:		ZIP Code:	TF10 8NB
Email:	FieldRobot2019@live.harper.ac.uk		
Webpage:	https://www.facebook.com/2019ERIC/		

THE MACHINE			
W x L x H (cm):	45 x 80 x 50	Weight (kg):	11
Commercial or prototype:	Prototype	Total no. of wheels / no. driven wheels:	4 / 4WD
Drivetrain concept / max. speed (m/s):	4WD / 8m/s	Turning radius (cm):	68cm
Battery type / capacity (Ah):	2 x 11.1V LiPo/ 6Ah	Total motor power (W):	30
No. sensors internal / external: Sensor(s) type(s):	4 x 2D LiDAR Laser scanners (external), 1 x PIXY CMU Cam5 (external), 1 x Nine degrees of freedom (external)		

Controller system software description (sensor data analysis, machine control etc.)
Arduino Mega 2560 used as central operator supervisory control in a distributed control system where Arduino Micro's were used as controls for each sensor communicating through I²C.
Controller system hardware description (motor controller, computer etc.)

Laptop was used for remote monitoring through XBee. Arduino Micros were used for sensor processing, motor controller for speed, servos for steering inputs and Arduino Mega for vehicle control through I^2C bus.
Short strategy description for navigation and applications
Feedback was used from the 2D LiDAR sensors to keep the robot central to the rows with the turning assisted by nine degrees of freedom sensor. A PIXY cam was used to sense for weed detection with a simple sprayer system for weed spraying.
These are the commercial team sponsors & partners (if there are)
The Douglas Bomford Trust

6. Field Robot Event Design Team

"HELIOS evo"

Field Robot Event Design Team (FREDT)			
Names of team members:	David Bernzen Alexander Brümmer Tobias Lamping Steffen Lohmann Christian Schaub Enrico Schleef Julius Steinmatz Johann Thölking		
Name team captain:	Christian Schaub		
Instructor(s):	Tobias Blume		
Institution:	Technische Universität Braunschweig		
Department:	Institut für mobile Maschinen und Nutzfahrzeuge		
Country:	Germany	City:	Braunschweig
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 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):	4500 mAh	Total motor power (W):	250 W
No. sensors internal / external: Sensor(s) type(s):	2x LIDAR: SICK TIM 571 Odometry Unit Camera: Intel RealSense		
HELIOS evo is the next generation robot of the FRED-Team. Based on a proven chassis with four wheel drive and all wheel ackermann steering we added a completely new vehicle body.			

The main components are an agricultural rear lift system with 20 kg load capacity with integrated electrical- and fluid-lines as well as a new central electrical distribution and battery-management-unit. The vehicle body includes the main computer as well as the cooling and light system. This year we introduced a new dual LIDAR Sensor System 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 localized 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 with the main Computer via WIFI.

Short strategy description for navigation and applications

The goal in the first two tasks is to come to the end as quickly as possible by prediction of the plant rows and then turn around.

In task three, a T-shaped structure and two cameras attempt to detect obstacles and golf balls simultaneously in four rows. The optimum route created by this is then used in the task to reach all golf balls and reverse as few as possible. Of course, no obstacles should be run over while doing this.

These are the commercial team sponsors & partners

7. FarmBeast

“FarmBeast”

FarmBeast			
Names of team members:	Peter Bernad Rok Cafuta Gašper Fridrih Miha Kajbič Urban Kenda Jernej Mlinarič Žan Mongus Kristijan Polovič Matic Rašl Erik Rihter Luka Slapnik Erik Voh Aljaž Zajc Benjamin Založnik		
Name team captain:	Peter Bernad		
Instructor(s):	prof. dr. Miran Lakota dr. Jurij Rakun		
Institution:	University of Maribor, Faculty of Agriculture and Life Sciences		
Department:	Biosystems engineering		
Country:	Slovenia	City:	Hoce
Street / Number:	Pivola 10	ZIP Code:	2311
Email:	farmbeast@um.si		
Webpage:	http://farmbeast.um.si		

THE MACHINE			
W x L x H (cm):	52.7 x 65 x 50	Weight (kg):	35
Commercial or prototype:	Prototype	Total no. of wheels / no. driven wheels:	4
Drivetrain concept / max. speed (m/s):	0.5	Turning radius (cm):	75
Battery type / capacity (Ah):	6	Total motor power (W):	800

No. sensors internal / external: Sensor(s) type(s):	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 3 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, Šeško d.o.o

8. FloriBot

"FloriBot"

THE TEAM			
Names of team members:	Markus Joos, Fabian Finkbeiner, Andreas Hein, Richard Wienold, Adrian Männer, Manuel Hespelt		
Name team captain:	Markus Joos		
Instructor(s):	Prof. Dr.-Ing. Torsten Heverhagen		
Institution:	Heilbronn University of Applied Sciences		
Department:	Faculty for Mechanics and Elektronics (T1)		
Country:	Germany	City:	Heilbronn
Street / Number:	Max-Planck-Str. 39	ZIP Code:	74081
Email:	markus.joos@hs-heilbronn.de		
Webpage:	floribot.de		

THE MACHINE			
W x L x H (cm):	50 x 78 x 70	Weight (kg):	20
Commercial or prototype:	Prototype	Total no. of wheels / no. driven wheels:	4/2
Drivetrain concept / max. speed (m/s):	differential wheeled robot/ 2 m	Turning radius (cm):	0
Battery type / capacity (Ah):	Li-Ion 25,2 V / 18	Total motor power (W):	200
No. sensors internal / external: Sensor(s) type(s):	Laser scanner / 1, Motor Encoder / 2, IMU / 1, Temperature / 1, Camera / 2		

Controller system software description (sensor data analysis, machine control etc.)
We are running the robot operating system based on Ubuntu Linux. For the programming of machine control and sensor data analysis, we are mainly using Matlab/Simulink with the robotics system toolbox

Controller system hardware description (motor controller, computer etc.)
Our Computer is based on a Intel i5 processor with 16GB RAM and an SSD HD. Communication with sensors and actors is done with USB and RS232. Sensors are laser scanner, camera and wheel encoders. Actors are servomotors and a pan-tilt-unit
Short strategy description for navigation and applications
Our strategy is to extract a line feature out of the plants and to navigate according to the extracted line. At the end of the row, the robot drives a circle until it recognizes the row again. We using a industry camera from IDS to recognized the different balls on the field.
These are the commercial team sponsors & partners (if there are)
IDS Imaging Development Systems GmbH

9. DTU Maizerunners

“Maizerunner”

THE TEAM			
Names of team members:	Patrick Green Knudsen, Luka Kovac, Dimitrios Dagdilelis		
Name team captain:	Dimitrios Dagdilelis		
Instructor(s):	Ole Ravn, Nils Axel Andersen		
Institution:	DTU		
Department:	Elektro		
Country:	Denmark	City:	Kgs. Lyngby
Street / Number:	Building 326,	ZIP Code:	2800
Email:	naa@elektro.dtu.dk		
Webpage:	dimidagd.github.io/FRE2019log		

THE MACHINE			
W x L x H (cm):	34.5 x 70 x 87.	Weight (kg):	25
Commercial or prototype:	Prototype	Total no. of wheels / no. driven wheels:	4 / 2
Drivetrain concept / max. speed (m/s):	2	Turning radius (cm):	40
Battery type / capacity (Ah):	Lead 24v 7 amp/hour	Total motor power (W):	2 x 100w
No. sensors internal / external: Sensor(s) type(s):	Laser scanner HOKUYO URG, gyro cruizecore, wheel encoders		

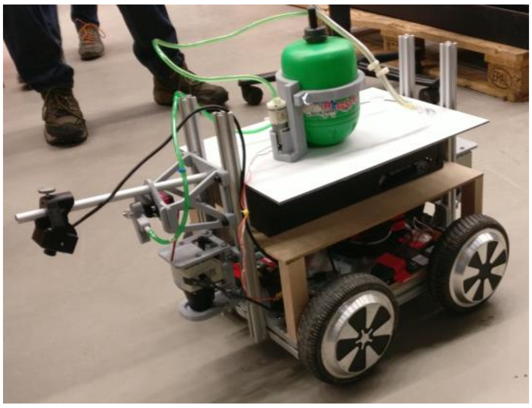
Controller system software description (sensor data analysis, machine control etc.)
Mobotware developed by DTU Elektro
Controller system hardware description (motor controller, computer etc.)
Motor controller: Atmel microcontroller RS232 breakboard Computer: Intel NUC M.B. UC7i3BNH, OS: Ubuntu 16.04 LTS

Short strategy description for navigation and applications
Row navigation: Laser data is used to guide the robot between the plant rows. Weed detection: Computer vision and RGB camera to detect position, pinhole model. Mapping: Particle filter SLAM Planning: Wavefront planning based on obstacle map Spraying : Spray nozzle and 12v water pump, actuated on a rotating axis.

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

10. Kamaro Engineering

“Dschubba”



THE TEAM: **Kamaro Engineering**			
Names of team members:	Sebastian Blickle; Anton Schirg; Michael Keppler; Johannes Barthel; Robin Eistetter; Kevin Daiß; Thomas Friedel		
Name team captain:	Thomas Friedel		
Instructor(s):	-		
Institution:	Karlsruhe Institute of Technology		
Department:	Teilinstitut für Mobile Arbeitsmaschinen		
Country:	Germany	City:	Karlsruhe
Street / Number:	Rintheimer Querallee 2	ZIP Code:	76131
Email:	mail@kamaro-engineering.de		
Webpage:	https://kamaro-engineering.de/		

THE MACHINE: **Dschubba**			
W x L x H (cm):	44cmx66cmx44cm	Weight (kg):	22kg
Commercial or prototype:	prototype	Total no. of wheels / no. driven wheels:	4
Drivetrain concept / max. speed (m/s):	Differential Steering 5m/s	Turning radius (cm):	0
Battery type / capacity (Ah):	Li-Ion, 4,4 Ah	Total motor power (W):	1kW
No. sensors internal / external: Sensor(s) type(s):	LIDAR, Camera, IMU, Compass		

Controller system software description (sensor data analysis, machine control etc.)
The robot utilizes LIDAR data for navigation and uses RGB(D) cameras for all other sensing purposes. A multitude of image analysis algorithms is used, ranging from traditional color-based classifiers to Deep Learning based image recognition technologies in the freestyle task.
Controller system hardware description (motor controller, computer etc.)
The system is built using low-cost off-the-shelf components such as hoverboard motors and standard PC hardware. Low-level electronics are controlled by a Raspberry Pi computer.
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 golf balls and a 3D-printed construction for spraying. In the freestyle task, we plan to apply deep learning for weed recognition and selective fertilizing.
These are the commercial team sponsors & partners (if there are)
Companies: SICK, Dunkermotoren, Schaeffler, Nozag, Igus, CONEC, Pepperl+Fuchs, Ganter Griff, Eurocircuits, NanoTec Institutes at the KIT: MOBIMA/FAST, WBK, AStA

11. Less is more

"The Dekracer"

THE TEAM			
Names of team members:	Vincent Aarts, Mark Geraets en Tim Houben		
Name team captain:	Vincent Aarts		
Instructor(s):	Jelle Adema & Andy Schierkes		
Institution:	Fontys hogenschool logistiek en techniek		
Department:	Mechatronica		
Country:	Nederland	City:	Venlo
Street / Number:	Tegelseweg 225	ZIP Code:	5912BG
Email:	v.aarts@student.fontys.nl		
Webpage:	https://fontys.nl/venlo/		

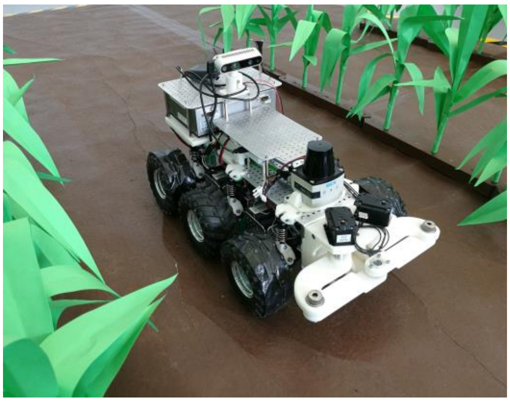
THE MACHINE			
W x L x H (cm):	60x60x30	Weight (kg):	20kg
Commercial or prototype:	Prototype	Total no. of wheels / no. driven wheels:	4
Drivetrain concept / max. speed (m/s):	2,1 m/s	Turning radius (cm):	90 cm
Battery type / capacity (Ah):	Li-ion battery 6,0 Ah	Total motor power (W):	76 Watt
No. sensors internal / external: Sensor(s) type(s):	1x Intel Realsense camera 2x encoder		

Controller system software description (sensor data analysis, machine control etc.)
The software to controll the motors is made in matlab simulink. The navigation part is made in python.

Controller system hardware description (motor controller, computer etc.)
TI launchpad to controll the motors and the steering servo. The deep learning is running on a laptop that is in the robot.
Short strategy description for navigation and applications
The navigation is based on deep learning
These are the commercial team sponsors & partners (if there are)
Greentechlab

12. MS UAS Team

"Ceres"



THE TEAM			
Names of team members:	Constantin Eckes, Marc Philipp Funcke, Jochen Korn, Piet van der Meulen, Jannis Wagner		
Name team captain:	Piet van der Meulen		
Instructor(s):	Jochen Korn		
Institution:	Münster University of Applied Sciences (MS UAS)		
Department:	Department of Mechanical Engineering		
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Street / Number:	Stegerwaldstr. 39	ZIP Code:	48565
Email:	jochen.korn@fh-muenster.de		
Webpage:	www.fh-muenster.de/maschinenbau/index.php		

THE MACHINE			
W x L x H (cm):	35 x 65 x 35	Weight (kg):	10
Commercial or prototype:	Prototype	Total no. of wheels / no. driven wheels:	6/6
Drivetrain concept / max. speed (m/s):	Differential drive / 1,4 m/s	Turning radius (cm):	0
Battery type / capacity (Ah):	2 x LiPo 3S 5 Ah	Total motor power (W):	6 x 20 = 120 W
No. sensors internal / external: Sensor(s) type(s):	1 x 2D LiDAR sensor Sick TiM 571, 1 x Intel Realsense depth camera D435, 2 x Maxon EPOS4 50/5 motor controller, 1 x IMU MPU-6050, 2 x motor encoder, 6 x motor temperature sensor, 1 x battery voltage sensor, 1 x RGB camera		

Controller system software description (sensor data analysis, machine control etc.)
The software of the robot runs on ROS Kinetic, which is used as the basic framework. The operating system of the central computing unit is Ubuntu Xenial. The functionality of the robot

is set up on the use of several already existing ROS nodes as well as additional added nodes. The additional nodes are implemented in C++. The ROS nodes are independent subprograms, which are able to communicate with each other. 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 a commercial 6WD robot platform with 6 metal gear motors. The suspension system has been strengthened by adding extra springs and shock absorbers. Furthermore, the robot is equipped with a Scara robot arm. The central computing unit is a Syslogic Compact industrial PC. The device is equipped with an Intel Celeron CPU (4 x 2 GHz), 4 GB DRAM and 128 GB SSD. The two Maxon motor controllers (one for each side) are connected to the main computer via RS232/CAN bus. The LiDAR sensor communicates with the main computer via Ethernet and the Intel Realsense camera via USB. The Scara robot arm is driven by two Dynamixel MX 28 actuators. The functionality of the battery voltage sensor and the motor temperature sensor is implemented on a seperate Arduino Uno board. An additional Arduino Nano board is responsible for the gear sensor (IMU) and another Arduino Nano board activates the optical communication. The micro-controllers communicate with the main computer via RS232. Finally, a Raspberry Pi single-board computer is used for the object detection based on a RGB camera. The RGB camera is connected to the RasPi via USB and the RasPi itself communicates with the main computer via Ethernet.
Short strategy description for navigation and applications
For detection of the maize plants the robot uses a LiDAR and a depth camera. Their data is evaluated by numerous algorithms to determine the position of the plants. Other ROS nodes use this information to navigate through the maize rows and do a turn at the end of a row. In addition to this, the data is used to create a map of the field, in which the weed patches and obstacles are noted. To detect these objects, the robot is equipped with a camera and a Raspberry Pi to evaluate the data.
These are the commercial team sponsors & partners (if there are)
MS UAS, Department of Mechanical Engineering

13. TAFR Robotics

"TAFR"

THE TEAM	
Names of team members:	Tim Kambič, Žiga Brinšek, Janez Cimerman, Urban Bobek, Martin Turk, Pavel Remic Weiss, Gal Pavlin, Iza Burnik
Name team captain:	Tim Kambič
Instructor(s):	/
Institution:	TAFR Robotics (Zavod 404)
Department:	TAFR Robotics
Country:	Slovenia
City:	Ljubljana
Street / Number:	Mencingerjeva ul. 7
ZIP Code:	1000
Email:	info@tafr.si
Webpage:	tafr.si

THE MACHINE			
W x L x H (cm):	45x79x40	Weight (kg):	45
Commercial or prototype:	Prototype	Total no. of wheels / no. driven wheels:	4/4
Drivetrain concept / max. speed (m/s):	Dc motors 2m/s	Turning radius (cm):	0
Battery type / capacity (Ah):	LiPo 5Ah	Total motor power (W):	4x125W
No. sensors internal / external: Sensor(s) type(s):	stereo camera, 2d lidar, IMU, 4 encoders		

Controller system software description (sensor data analysis, machine control etc.)
Lidar data for navigation, camera for detection (task 3 and 4)
Controller system hardware description (motor controller, computer etc.)

Intel NUC with ROS, RoboClaw dc motor drivers with speed control
Short strategy description for navigation and applications
Using clustering on lidar data to detect rows and calculate controls.
These are the commercial team sponsors & partners (if there are)
Epilog d.o.o

14. WURking II

"WURking"

THE TEAM			
Names of team members:	Helena Russello; Henry Payne; Thijs Ruigrok; Sam Blaauw; Gwen Dawes; Haris Khan		
Name team captain:	Helena Russello		
Institution:	Wageningen University		
Department:	Farm Technology Group		
Country:	Netherlands	City:	Wageningen
Street / Number:	P.O. Box 16	ZIP Code:	6700 AA
Email:	helena.russello@wur.nl		
Webpage:	https://www.wur.nl/en/Research-Results/Chair-groups/Plant-Sciences/Farm-Technology-Group.htm		

THE MACHINE			
W x L x H (cm):	40*60*50	Weight (kg):	10
Commercial or prototype:	prototype	Total no. of wheels / no. driven wheels:	3 / 2
Drivetrain concept / max. speed (m/s):	Two wheels differential drive 2 m/s	Turning radius (cm):	0 cm
Battery type / capacity (Ah):	LiPo 4Ah	Total motor power (W):	2*350 W peak
No. sensors internal / external: Sensor(s) type(s):	1 4 IMU, webcam, lidar, wheel encoders and ultrasonic array		

Controller system software description (sensor data analysis, machine control etc.)
The robot runs Ubuntu 18.04 LTS with ROS melodic over a distributed internal network. The software is written in Python.
Controller system hardware description (motor controller, computer etc.)
Vsec motor controller, RasberryPi's and a Jetson Xavier
Short strategy description for navigation and applications
Robotic navigation is determined according to a sensor fusion strategy in combination with a state machine based control mechanism.
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