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.

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

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.

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. 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

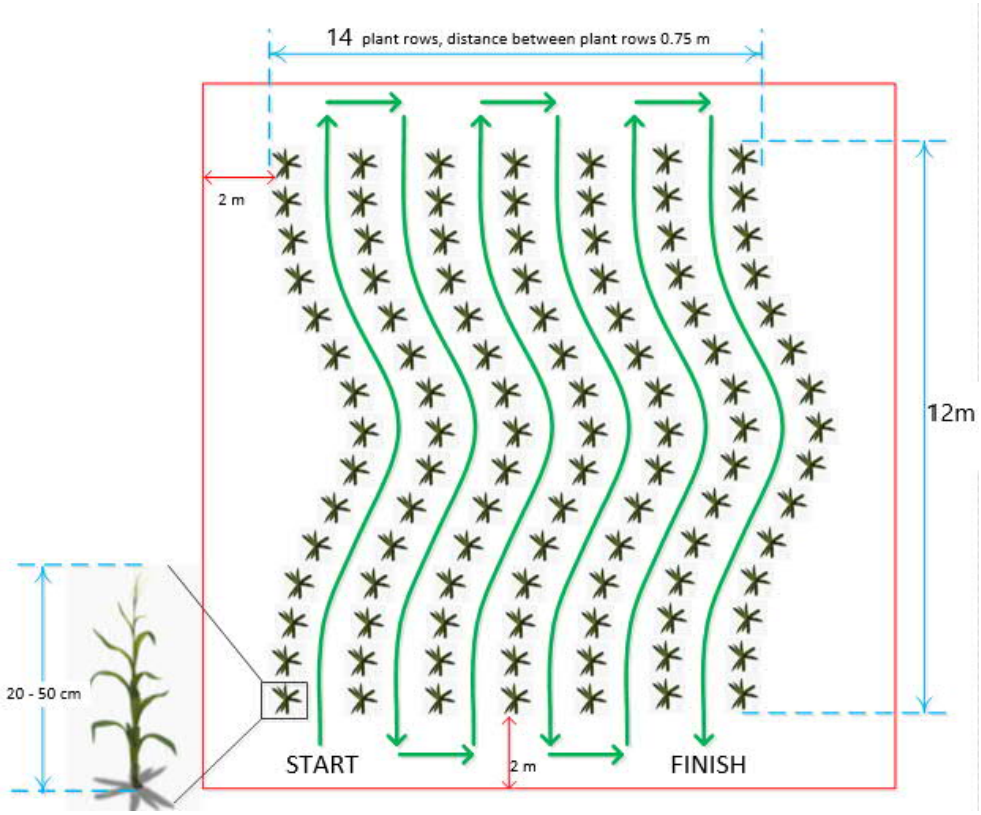
The jury will assess the (i) agronomic idea, the (ii) technical complexity and the (iii) robot performance by giving points from 0 (insufficient) to 10 (excellent) for each.

The total points will be calculated using the following formula:

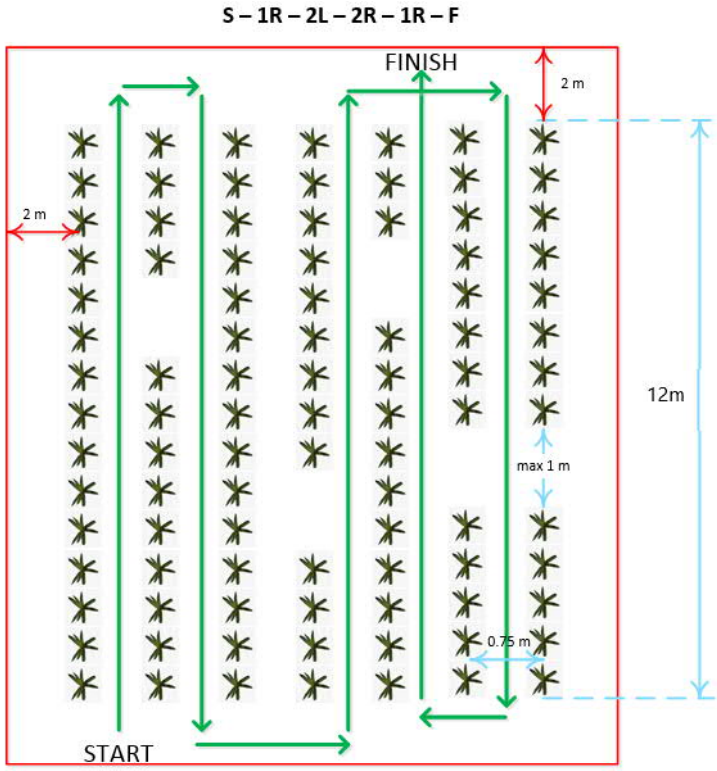
Final points = (agronomic idea + technical complexity) * performance.

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

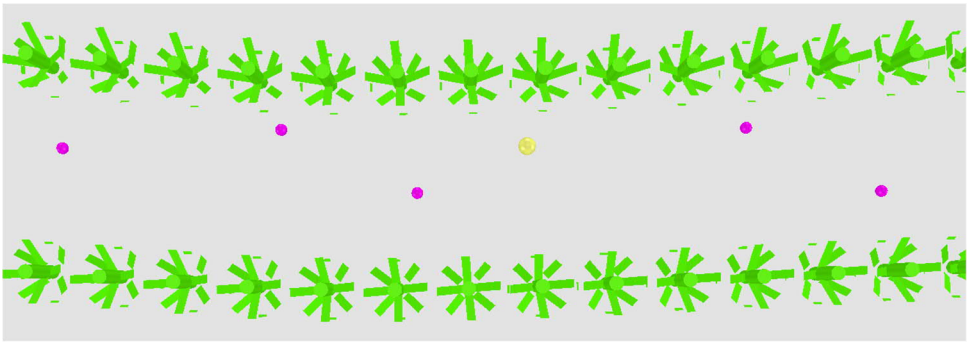
Appendix A



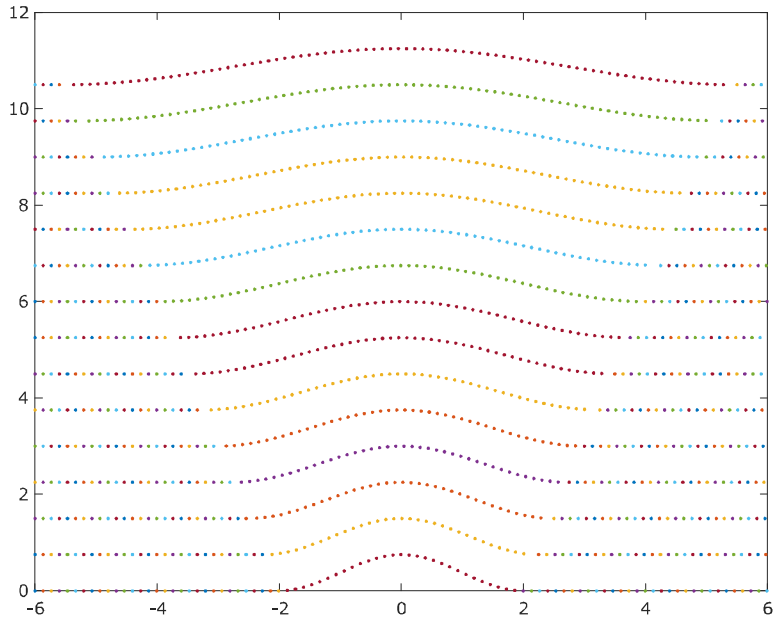
Picture 1 – Dimensions and row pattern for task 1.



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