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 competitive advantage by prohibited technologies. The teams should even, as far as possible, provide support to each other. Any observed or suspected cheating should be reported to the chair of the competition 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.

Five tasks will be prepared to challenge different abilities of the robots in terms of sensing, navigation and actuation: Basic Navigation, Advanced Navigation, Field Mapping, Weeding Application, and Free Style (option).

If teams come with more than one machine the scoring and ranking will always be machine related and not team related. The exception to this rule is that robots separate from the main one may be used during the Field Mapping task.

All participating teams must contribute to the event proceedings with an article describing the machine in more details and perhaps their ideas behind or development strategies.

In 2016 one of the most significant change was that NO team members was allowed to be in the inner contest area while the machine was competing. The robot operator must remain in the designated control area while the robot is working. If the robot fails to proceed, it has to be stopped from the control area with a remote switch. The team member who activated the remote switch can then go to the machine and manually correct it. The team member who activated the remote switch must return to the control area before reactivating the robot. This procedure is intended to ensure that, as far as possible, robots operate autonomously.

0.1. General rules

The use of GNSS receivers is NOT allowed except for the Free Style in Task 5. The focus for the other tasks shall be on relative positioning and sensor based behaviours.

Teams considering the use of GNSS for task 5 should be aware that the competition is being held indoors where satellite signals are very poor.

Field conditions

The Field Robot Event 2017 will be held indoors in the Soil Hall at Harper Adams University. The running surface will be sandy clay loam soil which will be cultivated and then lightly rolled to form an even tilth. The competition area will be illuminated by artificial LED lights from above. Some natural daylight will also illuminate the competition area.

The ‘field’ (figure 1) will comprise fifteen 10m long rows of maize plants growing approximately 0.75m apart. Adjacent plants within a row will be 20-30cm apart. The crop plant in task 1 to 4 will be maize (corn). The maize plants will have a height of 20 - 50 cm. The rows will be predominantly straight, but may exhibit a curvature of up to 0.75m across the length of the row. A red 50 mm wide textile tape will be laid in the field 2m from the plants at the ends of the rows to represent the boundary of the field. The robot must not cross this line.

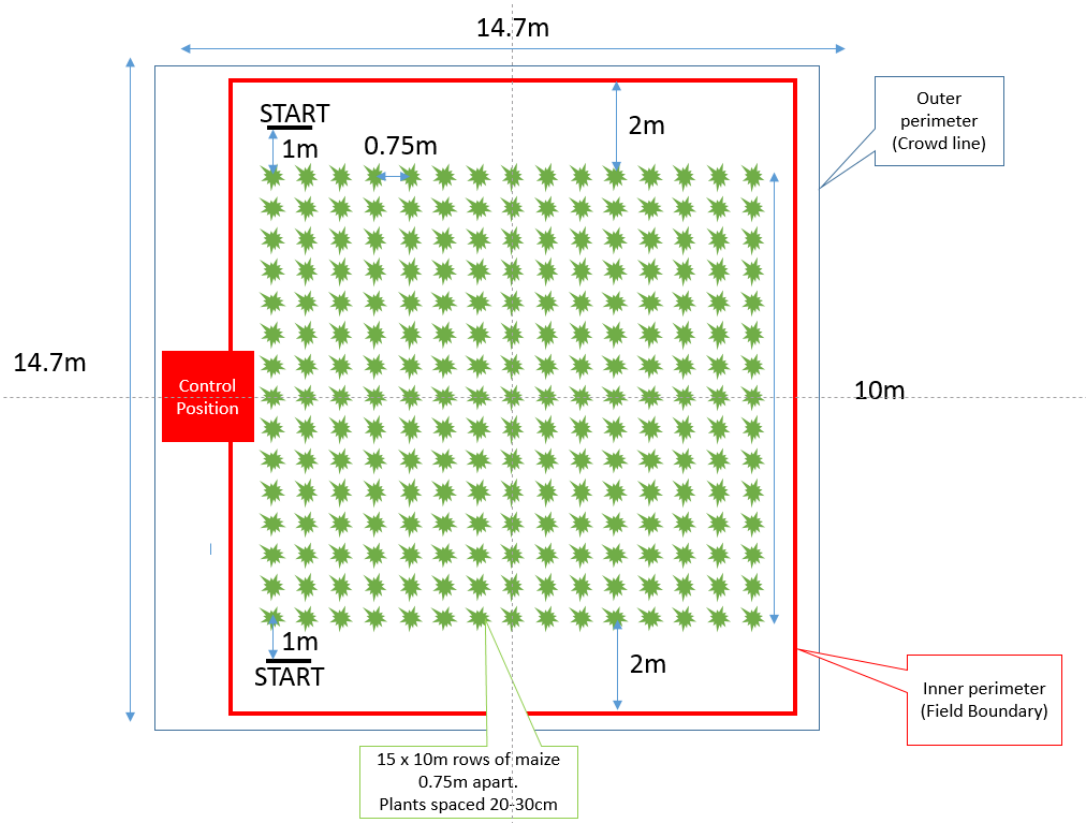

Figure 1: layout of the field for tasks 1-4

Damaged plants

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

Parc fermé

All robots must be moved to parc fermé before the first robot starts each task. No modifications – mechanical or electronic may be made to robots in parc fermé. All PC connections (wired and wireless) have to be removed or switched off and the activation of a battery saving mode is recommended. Parc fermé regulations are intended to avoid the possibility of robots competing later gaining an advantage by observing the performance of preceding robots. The starting order will be random. As each robot starts a task the next team to compete should make themselves ready to remove their robot from parc fermé.

Navigation

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

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.

During start, the robot is placed at the beginning of the first row. The starting line is located 1m from the start of the first row of crop and will be marked by a white line. All parts of the robot must be behind the start line before starting the task. For signalling 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 be brought back into the parc fermé. If the robot fails twice, the robot will be excluded from that task.

Start & Stop Controller

All robots must be equipped with and connected to one wireless remote START/STOP controller. Remote displays showing data from the robot are allowed but the operator must not interact with them.

Other remote controllers besides the START/STOP controller are strictly prohibited to be used at any time.

The remote controller must be a device with two buttons clearly marked START and STOP. Buttons may be physical switches or virtual switches on a touch screen. The use of a latching rocker switch with ON and OFF positions is also allowed provided it is marked START and STOP. If a computer keyboard is used for this function then the keys that operate the START and STOP functions must be labelled clearly.

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.

Any button of the remote controller may not be touched for more than one second at time. In other words, a button, which has to be pressed all the time, is not allowed. 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 in the control area. Only one nominated member of the team may touch the START and STOP inputs of the remote controller. Any remote display must be placed on the same table in the control area.

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.

Making corrections when the robot is STOPPED

The operator is permitted to stop the robot using the remote controller at any time if they observe that the robot is out of control or unable to continue the task without manual intervention. Operators may also be instructed to stop the robot by a competition official if it is likely to cause excessive damage to plants or is in a dangerous condition. In either case the robot must be stopped using the designated STOP button.

The timing of a task will continue while the robot is STOPPED.

In order to avoid disqualification it is recommended to install some indicator onto the robot to show that the robot is in STOP mode before entering the field.

During any task, when the robot has been STOPPED using the remote controller, the nominated operator alone is permitted to enter the field to make adjustments to the robot. No other team members are allowed in the field at any time while a robot is competing. While the robot is STOPPED the operator is permitted to operate buttons on the robot itself, e.g. to change the state of the navigation system or reset the robot.

While the robot is STOPPED the operator may also manually correct the position of the robot. Carrying the robot is only allowed after significant navigation errors in order to bring it back to the last correct position. The operator is allowed to rotate - not to move - the robot in the field. The only exception for moving is when it is necessary to relocate the robot to avoid damage to plants. In this case the robot must be moved the minimum distance, back along its track, to ensure that further plant damage is not caused.

Observers

Due to the fact that it can be difficult for the operator to fully monitor the robot's behaviour from a large distance, another team member is permitted to act as an observer. The observer must be nominated before the start of the task and is permitted to be inside the perimeter of the field but must remain outside the growing area. 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.

Unmanned aerial vehicles.

The mass of any unmanned aerial vehicle must not exceed 7kg. A net will be fixed at a height of 4m above the field, surrounding it on all sides, to ensure that unmanned aerial

vehicles cannot leave the field. Unmanned aerial vehicles must only be operated inside this netted enclosure, or the identical practice area, during the field robot event.

0.3. Awards

The performance of the competing robots will be assessed by an independent expert jury committee. Beside measured or counted performance parameters, creativity and originality will also be evaluated.

There will be an award for the first three ranks of each task. The results of the basic navigation (1), advanced navigation (2), field mapping (3), and weeding (4) tasks will contribute towards the overall competition score.

Points will be given as follows:

Rank	1	2	3	4	5	6	7	8	Etc…
Points	30	25	22	20	19	18	17	16	Etc…

Failure to compete in a task will score 0 points. If two or more teams have the same number of points after all four tasks, the team with the better placements during all four tasks (1, 2, 3 and 4) will be ranked higher. If a two or more teams remain tied then the tied teams will be asked to run one of the four tasks again.

1. Task “Basic navigation” (1)

1.1. General description

For this task the robot has three minutes to navigate as far as possible between the rows of maize plants, starting in the first row and travelling sequentially into rows 2, 3, 4 etc. (figure 2). On the headland, the robot has to turn within the 2m field boundary and return in the adjacent row. This task is all about accuracy, smoothness and speed of the navigation operation between the rows.

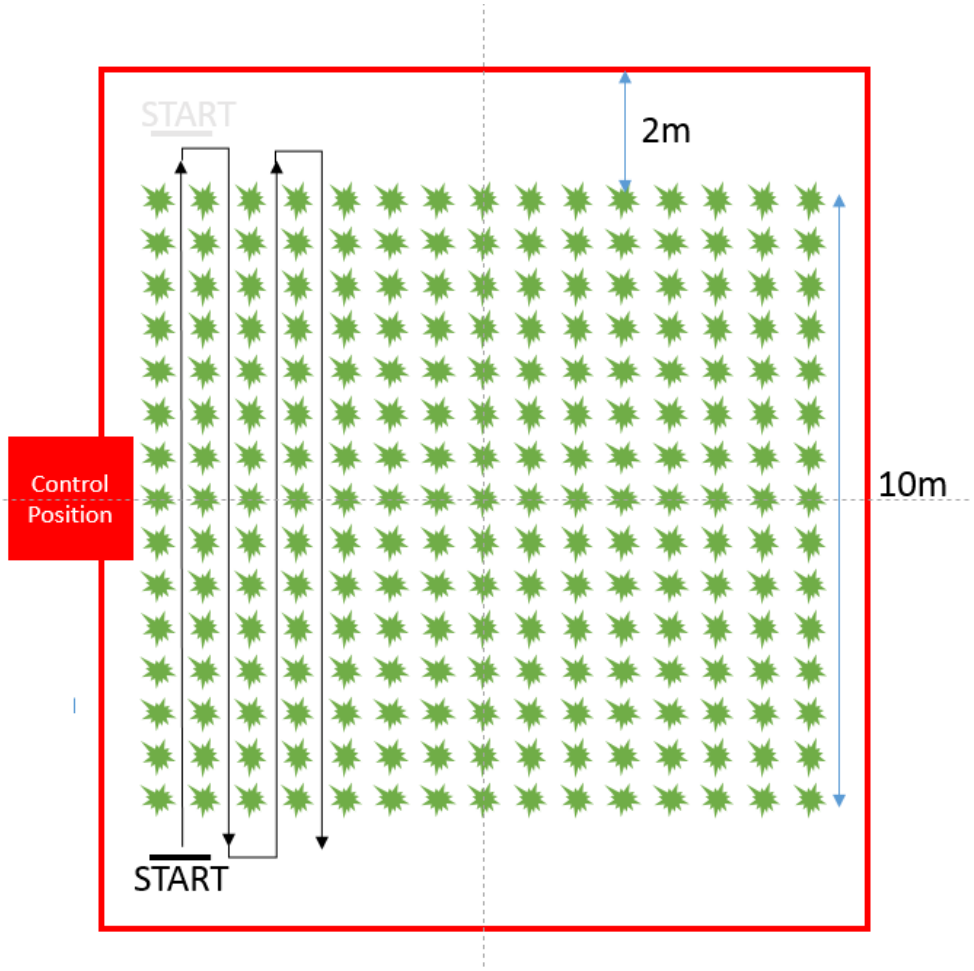

Figure 2: Task 1 Basic Navigation

1.2. Field conditions

Random stones will be placed along the path to represent a realistic field scenario. The stones will not exceed 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, the robot must have ground clearance of this amplitude at minimum, and the robot must be able to climb over obstacles of max 25 mm height.

1.3. Rules for robots

The robot will start the task from the start line. The start line may be on the left or right of the field. The position of the start line will be notified to the teams before the start of the task.

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

1.4. Penalties

Crop plant damage by the robot will result in a penalty of 1 meter per plant.

Manual intervention to move or adjust the robot will result in a penalty of 1 meter for each time the robot is STOPPED.

1.5. Assessment

The distance travelled in 3 minutes is measured. If the end of the field is reached in less than 3 minutes the remaining time will be used to calculate a bonus factor = total distance x 3minutes/measured time.

The total distance includes travelled distance and the penalty values. Distance and time are measured by the jury officials.

The task completing teams will be ranked by according to the total distance values.
The best 3 teams will be rewarded.

2. Task “Advanced navigation” (2)

2.1. General description

Under real field conditions crop plant growth is not uniform. Sometimes plants may fail to germinate or may be attacked by pests. We will approach these field conditions in the second task.

As in task 1 the aim is to navigate as far as possible between the rows within 3 minutes. However in this task the robots have to follow a certain predefined path across the field. 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 at row entries.

The robot must drive the paths in the order given before the start of the task. 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.

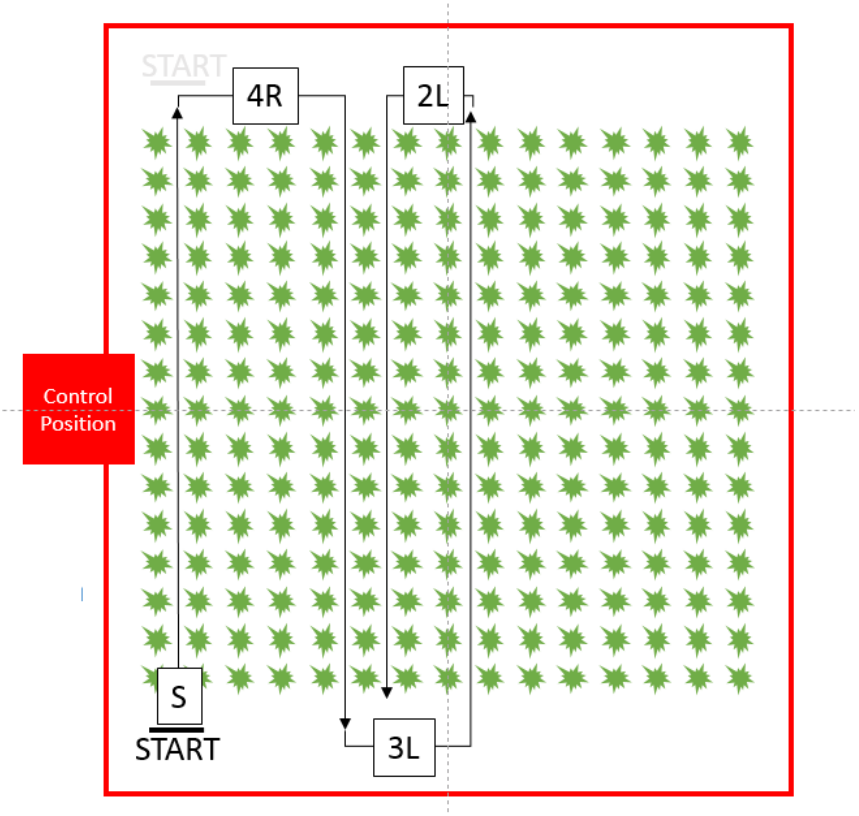

Figure 3: Task 2 Advanced Navigation

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 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.

2.3. Penalties

Crop plant damage by the robot will result in a penalty of 1 meter per plant.

Manual intervention to move or adjust the robot will result in a penalty of 1 meter for each time the robot is STOPPED. The robot must be STOPPED if it navigates into the wrong row.

2.4. Assessment

The distance travelled in 3 minutes is measured. If the end of the field is reached in less time, this time will be used to calculate a bonus factor = total distance x 3minutes/measured time.

The total distance includes travelled distance and the penalty values. Distance and time will be measured by the jury officials.

The task completing teams will be ranked by according to the total distance values.
The best 3 teams will be rewarded.

3. Task “Field mapping” (3)

3.1. General description

In this task teams have 5 minutes to map the field using autonomous systems, recording the positions of weeds represented by pink golf balls and obstacles represented by yellow tennis balls. Task 3 is conducted on the area used in tasks 1 and 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.

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. A possible example is illustrated in figure 4.

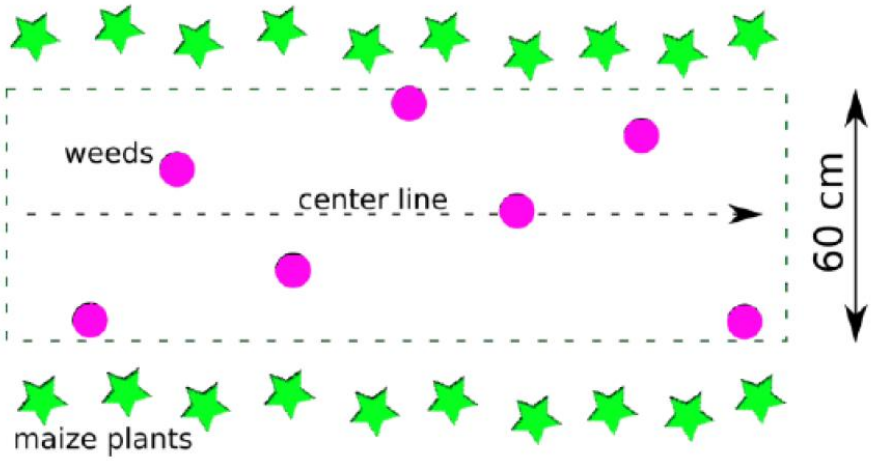

Figure 4: Possible locations of weeds for tasks 3 and 4

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

For this task teams are permitted to use systems other than the main robot, for example an unmanned aerial vehicle or a swarm of small robots. Any system used in this task must still operate autonomously.

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.

Teams can nominate whether they wish to indicate the detection of weeds and obstacles separately from the mapping of their locations. Once the nomination has been made then that method must be used for the task.

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.

Option 1

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.

Option 2

A single robot, a swarm of robots or an unmanned aerial vehicle survey the field to produce a map which indicates the positions of weeds and obstacles in graphical form. The same rules for false positives and negatives will be applied as in option1. The Jury will judge whether the positions of the weeds and obstacles shown on the map are accurate. The map may be generated in real time or can be shown to the Jury at the end of the run. The team will have 2 minutes from the end of the run to produce the map and show it to the Jury.

The map will be required to complete task 4.

3.4. Penalties

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.

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.

3.5. Assessment

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

Each correctly identified and located weed or obstacle (true positives) will be awarded 6 points per weed or obstacle.

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 will 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 which is independent of the main robot, but this process must be completed within the 10 minute time window.

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.

4.4. Penalties

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.

4.5. Assessment

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 is 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 10 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: (agronomic idea + technical complexity) x performance.

Task 5 is optional and will be awarded separately. It will not contribute to the overall competition results.