2. The FRE24 Competition

2.1 Remarks

- There are no plans to offer a virtual participation or a competition in a virtual environment.
- The roganising team tries to describe the tasks as good as possible, but all teams should be aware that we may have to modify the rules before or even during the contest in order to clarify and resolve any ambiguities. These changes will be decided by the members of the jury and all teams will be informed about the changes.
- The results are related to a team, not a field robot. This means that a team might use more than one robot for the different tasks, but only one for each task.
- If the robot fails to start within one minute after the start signal, it is allowed to perform a second start after the last robot has finished this task. There will be no third attempt.

2.1.1 General Rules

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

Crop plants: The crop plants for the tasks is maize (corn) or Zea Mays . The maize plants will have a height of approximately 20 - 40 cm. The concrete appearance of the crop plants is depending on the location specific growing conditions.

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

Parc fermé: During the contests, all robots have to wait in the parc fermé from the beginning on. Therefore, no more machine modification to change the machine performance is allowed during the task runs. All PC connections (wired and wireless) have to be removed or switched off and an activation of a battery saving mode is recommended. This shall avoid having an advantage not being the first robot to conduct the task. The starting order will be random. When a robot will move to the starting point, the next robot will already be asked by the parc fermé officer to prepare for starting.

Navigation: The drive paths of the robots shall be between the crop rows and not above rows for tasks 1 and 2. Damaged plants will be replaced by spare ones, to always ensure the same operation conditions for all the robots.

2.1.2 General Requirements for all Robots

1. *Autonomous mode*: All robots must act autonomously in all tasks except for the freestyle. Driving by any remote controller during the tasks is not allowed at any time apart from task 5. This includes steering, motion and all features that produce movement or action at the machine. Stopping and starting function for manual corrections of the machine is the only exception.
2. During *start*, the robot is placed at the beginning of the first row or the predefined starting point. The starting line is marked with a white line. Any part of the robot must not exceed the white line in the start. For signaling the start and end of a task there will be a clear acoustic signal. After the start signal, the robot must start within one minute. If the robot does not start within this time, it will get a second chance after all other teams finished their runs, but it must - after a basic repair - as soon as possible be brought back into the parc fermé. If the robot fails twice, the robot will be excluded from the task's starting list.
3. *Start & Stop Controller*: All robots must be equipped with and connected to one wireless remote START/STOP controller. Additional remote displays are allowed but without user interaction, e.g. notebook or laptop.
4. Preferably, the remote controller is a device with two buttons clearly marked START and STOP. Alternatively, the coding may be done with clear green and red colors.
5. 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.
6. 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.
7. 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.
8. 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.
9. The remote controller must be presented to the Jury members before the run. A jury member will watch the use of the START/STOP remote controller during the task execution. Other remote controllers besides START/STOP controller are strictly prohibited to be used at any time.
10. In each task, the robot must be started by using the remote controller START input, not pressing any buttons on the robot itself.
11. 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.
12. 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.
13. *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 on the robot to see that the robot is in STOP mode before entering the field in order to avoid disqualification.
14. The START/STOP operator is also responsible for the eventually manual robot corrections.
15. After leaving the remote control on the table, the operator is allowed to rotate - not to move - the robot in the field. The only exception for moving is when the robot may need to get

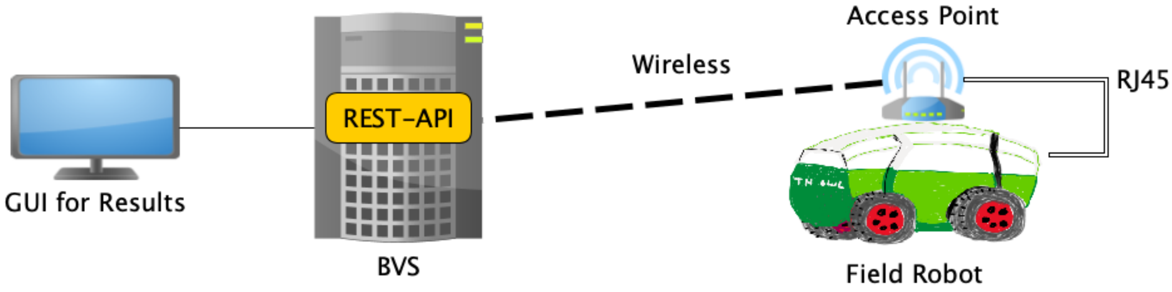

Fig. 2.1: Communication architecture for tasks 2, 3 and 4 including the field robot, an access point and the central benchmark and validation server (BVS).

back to the path if a wheel or track of the robot has collided with 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.

2.1.3 Awarding and Prizes

The performance of the competing robots will be assessed by an independent expert jury committee. Beside measured or counted performance parameters, also creativity and originality (freestyle) will be evaluated. There will be an award for the first three ranks of each task. All tasks together will yield a an overall competition winner.

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

2.1.4 REST Communication and Interface

Tasks 2, 3 and 4 require data exchange with a central benchmark and validation server (BVS). The BVS will provide a REST API and its definition will be published as an OpenAPI[1] definition in May. A test BVS will be up and running by midth of May. For the communication, the organising team will provide an access point[2] which has to be fixed on the field robot, e.g. by Velcro band. The field robot has to send its data via ethernet cable to the access point, no additional WLAN is required by the teams. The architecture looks as shown in fig. 2.1.

2.2 Description of the Tasks

2.2.1 Task 1: Navigation in a Maize Field

General Description

In this task, robots navigate autonomously through a maize field (see fig. 2.2) starting at the starting location S. Turning has to follow adjacent rows for tracks T_1 to T_n, e.g.
$S \Longrightarrow T_1 \Longrightarrow T_2 \Longrightarrow T_3 \Longrightarrow T_4 \Longrightarrow T_5 \Longrightarrow T_6 \Longrightarrow \ldots$
The distance between adjacent rows will be 0.75 m. Some of the plants in the rows may be missing, but not at the beginning or end of any row. The maize plants are expected to have a height of approx. 0.3 - 0.4 m.

[1] https://www.openapis.org
[2] Similar to the Gl.Inet Mini Smart Router https://store.gl-inet.com/collections/mini-smart-router.

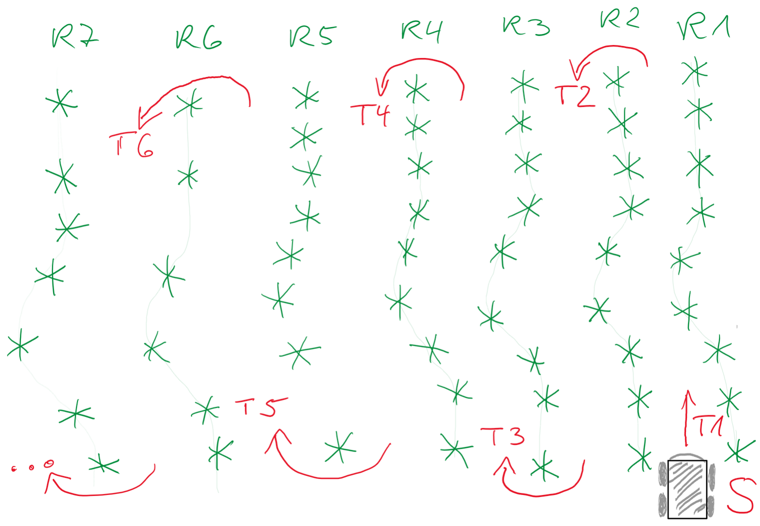

Fig. 2.2: Sketch of the maize area for tasks 1 and 2 with the starting point S (lower right), the rows R_i of maize and the Tracks T_j.

Rules for the Robots

Each robot has to start within 1 min. after the signal for the start. The maximum time is 3 min. for every field robot beginning with the individual start.

Scoring

The scoring P includes the travelled distance, the number of damaged plants causing a penalty and a time dependant and linear increasing bonus distance if the field robot finishes before the 3 min time slot has ended:

$$P_{Pask1} = P_{Distance} - P_{Penalty} + P_{Bonus}(t) \tag{2.1}$$

The penalty is $P_{Penalty} = 5m$ per plant, the bonus distance $P_{Bonus}(t) = 0.8m * t$ with t being the time in seconds the robot is faster than 3 min.

2.2.2 Task 2: Object Detection and Counting in a Maize Field

General Description

Task 2 is essentially an extension of task 1. In addition to the first task, the field robots have to count the number of plants in each row and present the results row by row immediately after finishing the individual rows by providing the data using the REST API. In addition to the plant counts for each row, a JSON logfile has to be provided immediately at the end of the task using an USB stick.

Rules for the Robots

Each robot has to start within 1 min after the signal for the start. The maximum time is 3 min. for every field robot beginning with the individual start.

Scoring

The scoring in this task depends on the fraction of correct plant countings. Only data from rows which have been completed are accepted.

$$P_{Task2} = \sum_{i=1}^{k} \left[1 - \frac{|N_{i,correct} - N_{i,counted}|}{N_{i,correct}} \right] - P_{Penalty} \tag{2.2}$$

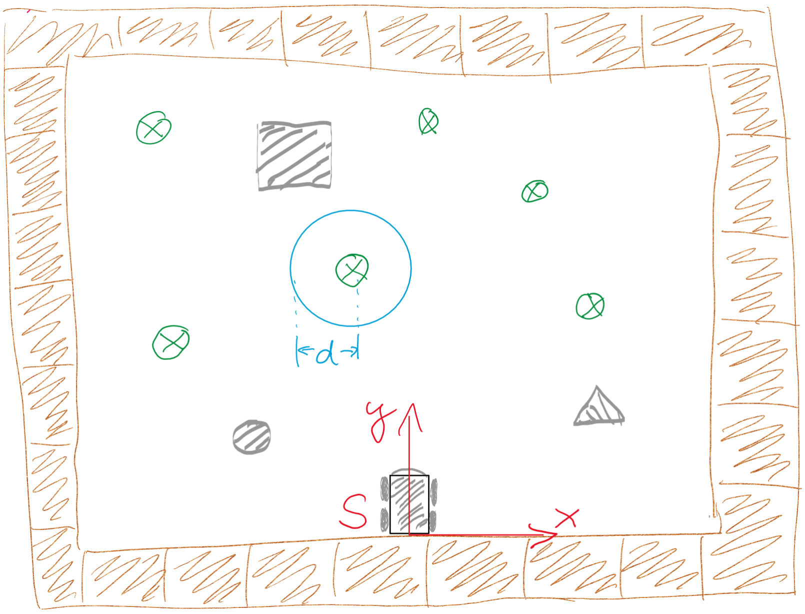

Fig. 2.3: Sketch of the grassland area for tasks 3 and 4 with the starting point S (lower center), the orientation of the coordinate system (red), obstacles (gray) and possible locations of the weed (green).

with the number $N_{i,correct}$ of plants existing in row i and the counted number of plants $N_{i,counted}$ in row i. Note that the first row is the one on the right hand side of the field robot when it starts. A penalty $P_{Penalty}$ will be applied for robots damaging maize plants:

$$P_{Penalty} = 5 * \frac{N_{crashedplants}}{N_{total}} \tag{2.3}$$

with the number of plants crashed by the robot $N_{crashedplants}$ and the total number of plants N_{total}.

2.2.3 Task 3: Mapping in a Grassland Area

General Description

In this task, the field robots have to work in a grassland area, see fig 2.3. The task is to find and map any weeds in the area. In order to support the localisation within the grassland area, it will be enclosed by a side fence, e.g. straw bales or something similar with a height of at least 0.3 m. The zero position of the coordinate system will be marked by a vertical board or wooden plank. The result data consisting of (x,y) data sets has to be provided by the field robot using the above mentioned REST interface (see section 2.1.4). The position has to be send as soon as the weed has beend detected. No data will be accepted after 3 min. and a ”Finished”-Token has to be send in order to indicate the end the search process. An additional JSON logfile should be available on request by the jury in the case of data transmission problems. Additional obstacles might be present in the grassland area. The weed will be represented by small artificial flowers[3] placed on the ground. The flowers may have any non-green VIS color. The dimensions of the quadratic grassland area are approx. 8 m x 8 m (as good as this can be achieved). The distance between the following objects is $\geq$ 1.0 m:

[3] See, e.g. `https://www.amazon.de/-/en/artificial-sunflowers-flowers-decorative-decoration/dp/B08SWGFLQS/ref=sr_1_2?crid=3TS5QB5RDBNUP`

- weed plant and weed plant,
- weed plant and obstacle,
- weed plant and side fence .

The progress of the robot might be visualised non-officially on a display.

Rules for the Robots

Each robot has to start within 1 min after the signal for the start in the starting area. The maximum time is 3 min. for every field robot beginning with the individual start. There is no predefined track. The direction of x and y will be defined by the starting area and the initial orientation of the field robot.

Scoring

The score depends on the number of correctly mapped weed plants. The required accuracy d is 0.15 m for the distance between real and mapped location.

$$P_{Task3} = \frac{N_{correct} - N_{incorrect}}{N_{total}} \quad (2.4)$$

with $N_{correct}$ being the number of correctly mapped weed positions, $N_{incorrect}$ the number of incorrectly mapped weed positions and N_{total} the total number of weed plants in the grassland area. If the distance l between real location and measured location is greater than the required accuracy d, the location of the weed will contribute to $N_{incorrect}$. As a consequence, P_{Task3} may become negative, if a great number of positions is send.

2.2.4 Task 4: Application in a Grassland Area

General Description

In task 4, the locations of the weed will be available via REST at the beginning of the individual field robot run and has to be downloaded by every field robot. The weed and the grassland area are the same as in task 3. The field robot has to move to the locations of the weed and apply any weed control. There is no predefined mechanism for the application, but the application has to be verifyable by the jury members and removing the weed by driving over it will not result in any scoring points.

Rules for the Robots

Each robot has to start within 1 min after the signal for the start in the starting area. The maximum time is 3 min. for every field robot beginning with the individual start . There is no predefined track. The direction of x and y will be defined by the starting area and the initial orientation of the field robot. The starting area will change from robot to robot.

Scoring

The scoring contains contributions $a_{i,distance}$ for reaching the weeds (distance < 0.5 m: 1 point, distance < 0.15 m: 2 points) and $a_{i,application}$ for the application of the weed control (non-visible: 0 points, visible: 1 point, clearly visible: 2 points) for each of the k weeds:

$$P_{Task4} = \sum_{i=1}^{k} \left(a_{i,distance} + a_{i,application}\right) - \sum_{j=1}^{n} b_{j,application} \quad (2.5)$$

with $b_{j,application} = 1$ for incorrect positions of application and 0 otherwise .

2.2.5 Task 5:Free Style

General Description

In the last task the teams are encouraged to present ideas and their implementations for self-chosen topics. Each team has to present the idea and explain the solution. Any ideas with a strong agronomic motivation is welcome.

Rules for the Robots

There are no specific rules for this task.

Scoring

Scoring is based on the number of points $r_{agronomic}$ for the agronomic idea, $r_{techn.complexity}$ and for the field robot's performance $r_{performance}$ with $r_x = 0 \ldots 5$.

$$P_{Task5} = r_{agronomic} + r_{techn.complexity} + r_{performance} \tag{2.6}$$

2.2.6 Overall Result

For the overall result, the teams will get points according to their individual performance in each task. i.e. for n teams, the best team in a task will get n points, the second one $n-1$ etc. and the last one 1 point. The sum of the team's results will be divided by the number N of teams multiplied by 4:

$$R_{overall} = \frac{R_{Task1} + R_{Task2} + R_{Task3} + R_{Task4}}{4 * N} \tag{2.7}$$