ECHORD++ Flooring Fellow

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D3.1
Report on F2 testing and validation

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PU	Public	
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RE	Restricted to a group specified by the consortium (including the Commission Service)	
CO	Confidential, only for members of the consortium (including the Commission Service)	**CO**

Document History

Version	Date	Author	Summary of Main Changes
1.0	21-01-2016	Giancarlo Teti (RT)	First version of the Deliverable and table of contents
1.1	30-12-2016	Giancarlo Teti	Final Version

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Executive summary

Deliverable D3.1 “Report on F2 testing and validation” describes the activities carried out in task T3 “Testing and validation” and reports the results of the testing and the evaluation of the robot performance.

The document is organised as follow: Section 1 describes briefly a test and demonstration of the robot done to professional floor tile manufacturers and construction site field operators and the comments and suggestion received for improving the system. Section 2 describes the modifications and improvements. Section 3 and 4 report results of the tests and the evaluation of performances.

1 Preliminary tests and indications for improvements

1.1 Test and demonstration to professional floor tile manufacturers

A demonstration to professional floor tile manufacturers, operators of the construction site field and IMER marketing staff, has been done at the IMER facilities on October 13, 2016. Among the others, the professional floor tile manufacturer involved at the beginning of the project for defining requirements and specification participated to the test.

Test has been done in a small room of about 9 m^2 in which grout has been spread and the robot was programmed for a standard cleaning program: followed the perimeter of the room, and run a spiral cleaning trajectory.

Figure 1: some picture of the robot during the demonstration.

Beside the general positive impact on the robot and its design and functions, comments and suggestions for improvements have been collected. The quality of the cleaning of the sponge has been considered similar to those of manual machine, and the set up procedure easy and appropriate. Weight and portability of the robot has been considered good as well.

The following main suggestions have been collected and taken into account for improvements:

- Execution of 45° cross cleaning trajectories: this is required to avoid parallel or perpendicular passage of the sponge on the tile gaps which cause the grout to be removed also from the gap.
- Cleaning speed reduction: the robot should move slower to assure good cleaning quality. Good speed has been estimated in 0.05/0.07 m/s. On the contrary the tool speed has to be increased up to 35 RPM.
- Fast cleaning program: a cleaning of the floor is required after grout removing according to the standard legislation on tile floor construction quality assurance. This is can be done with

the robot moving at high speed: the maximum speed of the robot (i.e. 0.25 m/s) has been considered good for this function.

- The percentage of cleaned floor surface has to be increased: in particular strategies to clean the floor close to the walls have to be implemented.
- Dry vacuum cleaner: this is an additional function and concerns the possibility to use the robot also for dry vacuum cleaning the floor, which is a common operations often performed in construction sites.

2 Technical improvements

On the base of the comments and suggestions received during the demonstration and in general during the test performed, the following improvements have been implemented:

- tool raising/lowering mechanism: to guarantee that while turning the sponge is not in contact with the floor as to avoid parallel or perpendicular sponge position with respect tile gaps.
- non absorbing track belts and new tracking wheels: to avoid the track belts to absorb and release grout during the operations which can affect quality cleaning.
- new tool motor reduction gear to increase tool speed: the old tool motor reduction gear (ratio 150:1) has been replaced with a new one (92:1) to guarantee more speed to the tool.
- new pump: the old pump has been replaced with a peristaltic pump which is more robust toward blockages due to the material (grout) flooding into the pump.
- new carter to cover laser and antennas.
- 45° cross cleaning plan: to avoid parallel or perpendicular sponge position with respect tile gaps during the cleaning.
- cleaning procedure improvements: cleaning refinement at the end of the plan to clean the floor close to the wall in the corners.
- user Interface improvements: to improve usability of the Smartphone interface.
- dry vacuum cleaners: to use the robot to remove water from the floor.
- software bug fixing and optimization

2.1 Tool raising/lowering mechanism

A motor from the automotive sector (Hella 6NW 009 424-791) has been added in the front part of the robot and a cam has been designed and realised for the motor shaft. The cam acts on the a bar positioned on the tool which cause the tool to slide up or down on the sliding guides. The position of the bar has been regulated in order to raising the tool 1.5 cm from the ground so as the sponge is not in contact with the floor. For the control of the motor, the auxiliary output for DC motor available on the main board has been used and the firmware of the board has been modified accordingly.

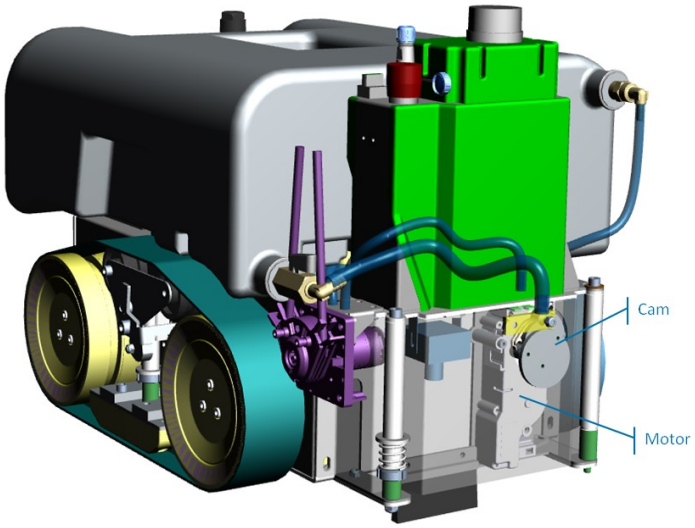


Figure 2: Mechanical design of the 2.1 Tool raising/lowering mechanism

2.2 Non absorbing track belts and new tracking wheels

New track belts have been realised in a different material to replace the old belts which were in spongy material. The new belts have enough grip such as the old one but do not absorb material from the floor. Moreover the belts and the wheels have been redesigned in order to guarantee more grip between them to avoid slippage of the belt on the wheel. In particular the belt foot and the wheel cavity have been modified.

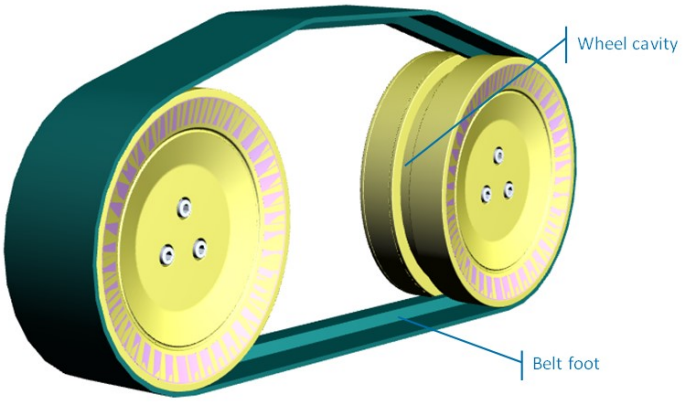


Figure 3: Redesign of belt foot and wheel cavity

2.3 45° cross cleaning plan

In addition to the standard spiral trajectory plan, a 'zigzag' trajectory plan has been implemented. The zigzag trajectory is used for those floors whose tiles are oriented parallel to the wall so as to cross tiles with an angle of about 45° avoiding parallel or perpendicular position of the sponge to tile gaps. On the contrary, the standard spiral plan is used for those floors whose tiles are oriented 45° with respect to the room walls. Both procedures use also the raising/lowering mechanism of the tool: the tool is raised whenever the robot turns and

lowered when the robot moves straight to reach the next point. Next figure shows results of the planner for both the two procedures.

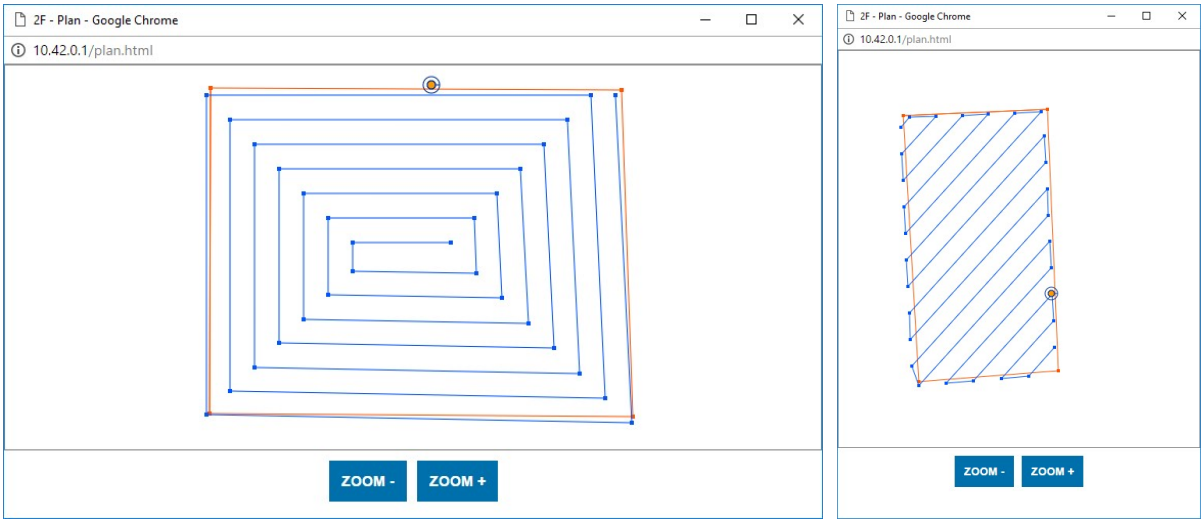


Figure 4: Standard spiral trajectory for a wall 45° tiles floor and a zigzag trajectory for wall parallel tiles floor.

2.4 User Interface improvements

The GUI for tablet and Smartphone has been completely redesigned in order to take into account indications collected during the demonstration and new functions developed. In particular indications where to use as much as possible icons instead of writing messages. Next figures show the GUI before and after the redesign:

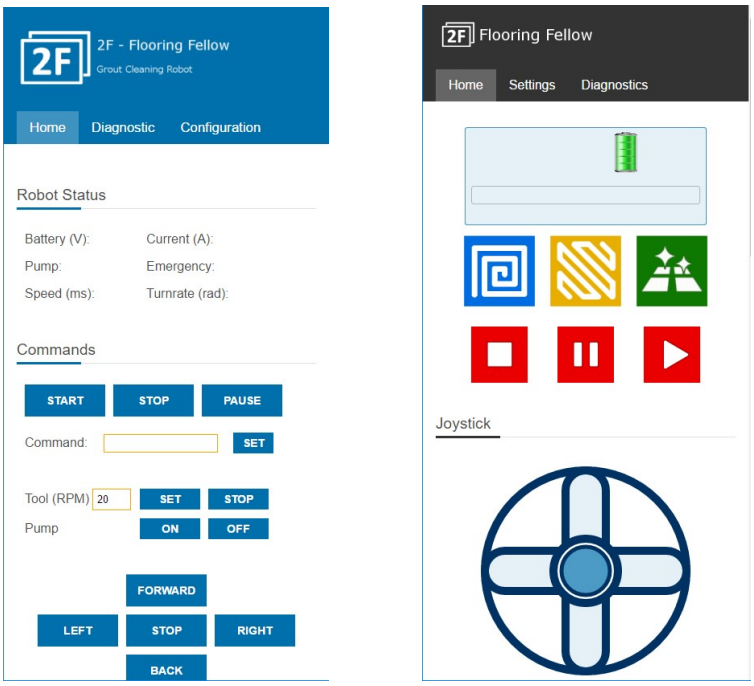
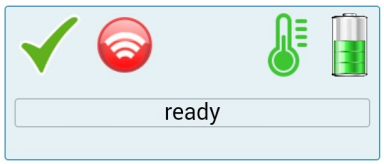


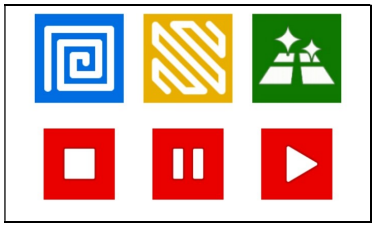
Figure 5: Redesign of GUI

Follow the list of modifications to the GUI:

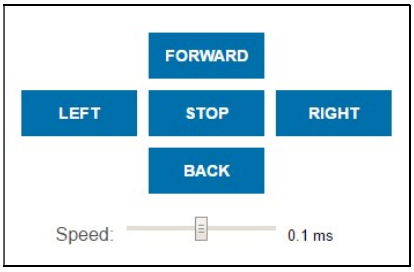
- addition of a status panel with icons indicating the robot status, emergency button status, battery level, tool motor temperature, etc.:

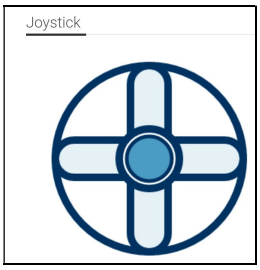


- addition of icon buttons for the three different programs: spiral trajectory, zigzag trajectory and fast cleaning with configurable speeds for robot tool and pump. Icons for pause, resume and stop the program:

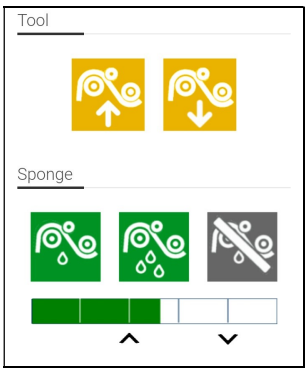


- replacement of buttons for remote control with a more intuitive pad similar to a real joystick:

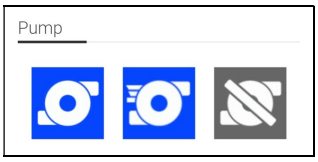




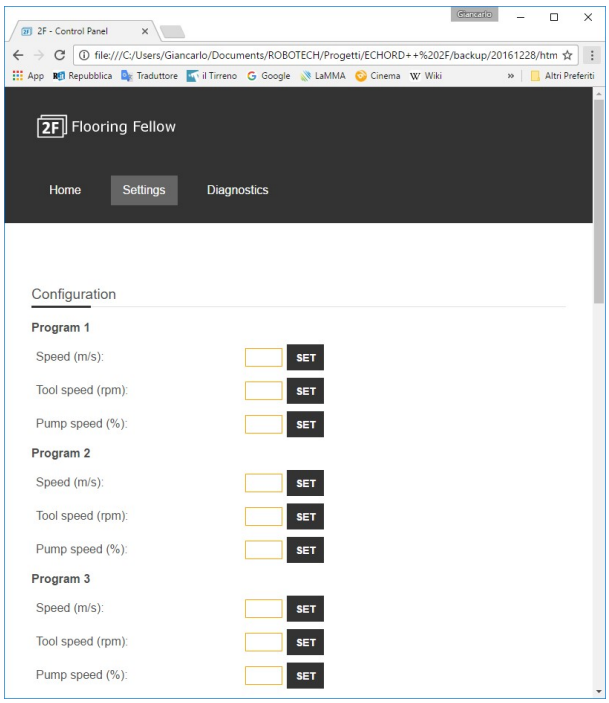
- icon buttons to raise/lower the tool, to start/stop the tool and slide bar to regulate tool squeezing mechanism. The slide bar level and colour is proportional to the tool motor current: colour is green when power is below 3A, yellow between 3A and 4A, and red over 4A. Below the bar two arrows indicate how to regulate the sponge squeezing mechanism: when the toll is up, current must be less then the 2A indicated by the first arrow. When the toll is down current must be less than 4A indicated by the second arrow:

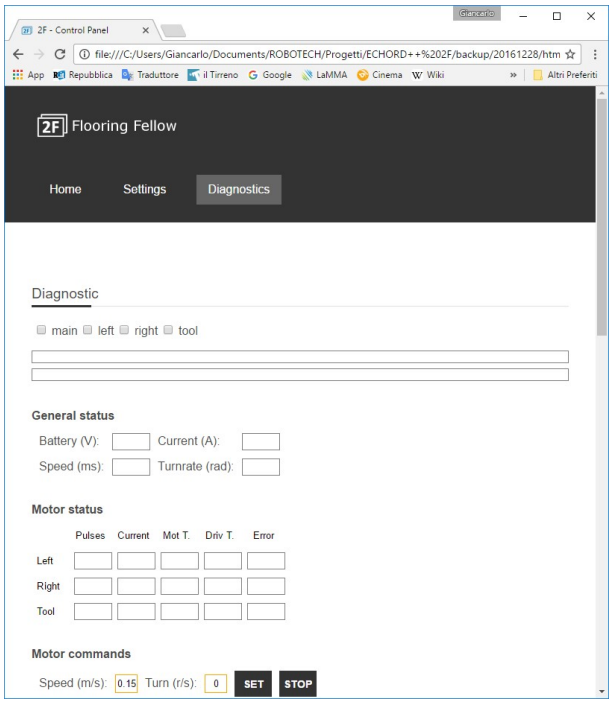


- icon buttons to start/stop the pump.



Configuration and diagnostic pages have been improved.





2.5 Dry vacuum cleaner

A commercial dry vacuum cleaner has been purchased and adapted to be mounted on the robot in place of the tank. To exploit modularity of the robot, the nozzle of the vacuum cleaner has been redesigned in order to be mounted in place of the tool. The firmware of the control board has been also modified to detect autonomously if the standard sponge tool or the dry vacuum cleaner is mounted on the robot. The development of the dry vacuum cleaner nozzle and its integration into the robot is still in progress.

3 Performance evaluation

Performance evaluation aimed at evaluating the robot performance in term of:

- **speed**: the typical speed of the robot during the cleaning operations
- **current consumption**: the current consumption during the cleaning operations
- **max current**: the max current consumption during the cleaning operations
- **productivity**: the cleaned area per hour
- **effectiveness**: the measure of the cleaned area with respect to the total area
- **battery life**: the duration of the battery (depends on current consumption)

Performances have been evaluated in an area of about 9 m^2 which has been purposively set up. Shape and dimension of the area changed slightly during the test between square or rectangular. Ten tests have been performed to evaluate the performances.

During the tests the following data have been collected:

- time: unix timestamp
- battery: instantaneous battery level in Volt
- Current: instantaneous current consumption in Ampere
- Linear speed: linear speed in m/s
- Rotational speed: the rotational speed in rad/s
- Robot Position: X and Y coordinate of the robot in the world
- Robot Orientation: orientation of the robot in the world
- Tool speed: tool speed in RPM
- Tool current: instantaneous current consumption of the tool in Ampere

Data have been collected every 100 ms for each test.

The following data have been measured manually:

- Area length
- Area width
- Cleaned area length
- Cleaned area width

The following data are available:

- battery V: the nominal battery voltage
- battery Ah: the nominal battery Ampere per hour or Watt per hour

The following measures have been computed on the base of collected data:

- Area dimension (m^2): area length x area width
- Dimension of cleaned area (m^2): cleaned area length x cleaned area width
- Effectiveness (%): dimension of cleaned area/ area dimension of cleaned
- Cleaning time (ms): end time – start time
- Productivity (m^2/h): dimension of cleaned area/ cleaning time in h
- average speed (m/s): average of linear speeds
- average current consumption: average of currents
- max current consumption: max currents
- run time: battery Ah
- Wh: average current consumption * battery Volt

As an example the following tables and figures report for three of the tests:

- the first and the last 20 data of data collected
- the trajectory plan produced by the path planner
- the positions of the robot during the plan execution
- the computed measures

The table in Section 3.4 report a summary of the value of the ten tests.

3.1 Result of Test 1

N.	time	battery (V)	current (A)	Linear speed (m/s)	Rotational speed (rad/s)	X	Y	H	Tool speed (rpm)	Tool Current (A)
1	1481725761789	27.00	0.61	0.00	0.00	0.00	0.00	0.00	0.54	0.00
2	1481725761889	26.90	0.86	0.00	-0.02	0.00	0.00	0.00	2.72	0.01
3	1481725761989	26.90	1.24	0.00	-0.04	0.00	0.00	0.00	3.53	0.18
4	1481725762089	26.80	1.64	0.00	-0.04	-0.01	0.00	0.00	7.61	0.48
5	1481725762189	26.70	2.09	0.00	-0.05	-0.01	0.00	0.00	12.50	0.91
6	1481725762289	26.60	2.87	0.00	-0.08	-0.01	0.00	0.00	17.12	1.33
7	1481725762389	26.70	2.50	0.00	-0.08	-0.01	0.00	0.00	21.20	1.52
8	1481725762489	26.60	2.27	0.00	-0.05	-0.01	0.00	0.00	24.46	1.55
9	1481725762589	26.60	3.05	0.01	-0.04	-0.01	0.00	0.00	26.63	1.61
10	1481725762689	26.60	3.39	0.02	-0.05	-0.01	0.00	-0.01	27.17	1.78
11	1481725762789	26.60	2.78	0.05	-0.04	-0.01	0.00	-0.01	27.99	1.81
12	1481725762889	26.60	2.73	0.06	-0.04	-0.01	0.00	-0.01	29.08	1.76
13	1481725762989	26.60	3.13	0.06	-0.05	-0.01	0.00	-0.01	28.80	1.94
14	1481725763089	26.60	2.31	0.06	-0.05	-0.01	0.00	-0.01	28.80	2.02
15	1481725763189	26.50	3.47	0.06	-0.03	0.02	0.00	-0.04	29.08	2.06
16	1481725763289	26.50	3.40	0.06	-0.03	0.02	0.00	-0.04	29.08	2.08
17	1481725763389	26.60	2.35	0.06	-0.02	0.02	0.00	-0.04	29.62	2.11
18	1481725763489	26.60	2.62	0.06	-0.02	0.02	0.00	-0.04	29.35	2.18
19	1481725763589	26.60	2.53	0.06	-0.02	0.02	0.00	-0.04	28.80	2.33
20	1481725763689	26.60	2.63	0.06	0.01	0.02	0.00	-0.04	29.35	2.35

Figure 6: Test 1, first 20 data collected during the test

N.	time	battery (V)	current (A)	Linear speed (m/s)	Rotational speed (rad/s)	X	Y	H	Tool speed (rpm)	Tool Current (A)
8141	1481726575789	26.00	3.99	0.07	0.01	0.85	-1.02	-0.12	30.71	2.55
8142	1481726575889	26.00	3.33	0.07	0.00	0.85	-1.02	-0.12	30.98	2.42
8143	1481726575989	26.10	2.92	0.07	0.02	0.85	-1.02	-0.12	30.98	2.32
8144	1481726576089	26.10	3.27	0.06	0.02	0.85	-1.02	-0.12	31.25	2.17
8145	1481726576189	26.10	3.27	0.06	0.00	0.88	-1.02	-0.11	30.98	2.08
8146	1481726576289	26.10	3.35	0.06	-0.01	0.88	-1.02	-0.11	31.25	1.90
8147	1481726576389	26.10	2.96	0.05	0.00	0.88	-1.02	-0.11	31.25	1.78
8148	1481726576489	26.20	2.95	0.05	-0.01	0.88	-1.02	-0.11	30.98	1.76
8149	1481726576589	26.20	2.92	0.05	-0.04	0.88	-1.02	-0.11	30.43	1.77
8150	1481726576689	26.10	2.91	0.05	-0.05	0.91	-1.02	-0.10	30.16	1.74
8151	1481726576789	26.10	3.09	0.05	-0.05	0.91	-1.02	-0.10	30.16	1.72
8152	1481726576889	26.20	2.83	0.05	-0.07	0.91	-1.02	-0.10	30.16	1.72
8153	1481726576989	26.20	2.42	0.05	-0.07	0.91	-1.02	-0.10	30.43	1.63
8154	1481726577089	26.10	2.86	0.06	-0.04	0.91	-1.02	-0.10	30.16	1.63
8155	1481726577189	26.20	2.58	0.06	-0.04	0.91	-1.02	-0.10	29.62	1.75
8156	1481726577289	26.20	2.92	0.05	-0.04	0.94	-1.03	-0.12	29.08	1.89
8157	1481726577389	26.20	2.94	0.04	-0.03	0.94	-1.03	-0.12	29.08	1.98
8158	1481726577489	26.10	3.27	0.03	0.00	0.94	-1.03	-0.12	29.08	2.03
8159	1481726577589	26.20	2.48	0.03	0.02	0.94	-1.03	-0.12	29.62	2.00
8160	1481726577689	26.50	0.54	0.01	0.03	0.94	-1.03	-0.12	6.52	0.08

Figure 7: Test 1, last 20 data collected during the test

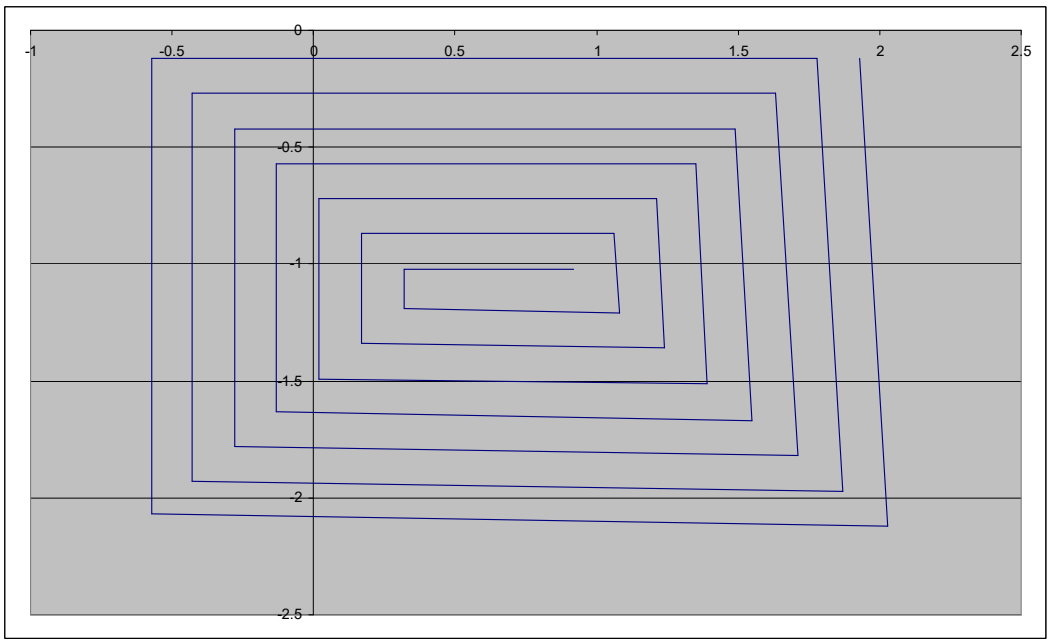


Figure 8: Test 1, Trajectory planned by the path planner

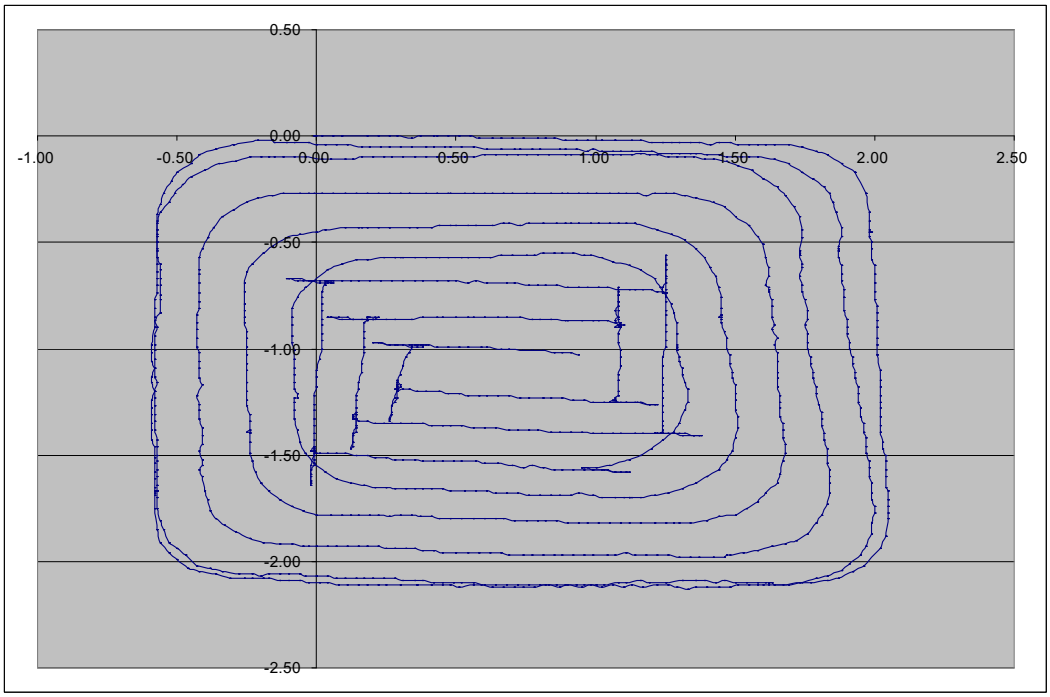


Figure 9: Test 1, Trajectory followed by the robot

Parameter	Value
area dimension	2.70 m 3.15 m = 8.51 m^2
dimension of cleaned area	6.84 m^2
effectiveness	6.84 / 8.51 = 80.37%
cleaning time	13.6 min
productivity	6.84 / 13.6 x 60 = 30.18 m^2/h
average speed	0.06 m/s
battery nominal voltage	25.9 V
battery nominal Ah	13.8
average current consumption	3.21 A
max current	4.93 A
battery run time	13.8 / 3.21 = 4.25 h
Wh per consumption	3.21 x 25.9 = 83.19 Wh

Figure 10: Test 1, performance during a test

3.2 Result of Test 2

N.	time	battery (V)	current (A)	Linear speed (m/s)	Rotational speed (rad/s)	X	Y	H	Tool speed (rpm)	Tool Current (A)
1	1483094486800	27.8	0.53	0	0	-0.96	-0.34	0.99	0	0
2	1483094486900	27.8	0.53	0	0	-0.96	-0.34	0.99	0	0
3	1483094487000	27.8	0.54	0	0	-0.96	-0.34	0.99	0	0
4	1483094487100	27.8	0.53	0	0	-0.96	-0.34	0.99	0	0
5	1483094487200	27.8	0.64	0	0	-0.96	-0.34	0.99	0	0
6	1483094487300	27.8	0.53	0	0	-0.96	-0.34	0.99	0	0
7	1483094487400	27.8	0.55	0	0	-0.96	-0.34	0.99	0	0
8	1483094487500	27.8	0.53	0	0	-0.96	-0.34	0.99	0	0
9	1483094487600	27.8	0.55	0	0	-0.96	-0.34	0.99	0	0
10	1483094487700	27.8	0.54	0	0	-0.96	-0.34	0.99	0	0
11	1483094487800	27.7	0.72	0	0	-0.96	-0.34	0.99	0	0
12	1483094487900	27.8	0.53	0	0	-0.96	-0.34	0.99	0	0
13	1483094488000	27.8	0.56	0	0	-0.96	-0.34	0.99	0	0
14	1483094488100	27.8	0.53	0	0	-0.96	-0.34	0.99	0	0
15	1483094488200	27.8	0.55	0	0	-0.96	-0.34	0.99	0	0
16	1483094488300	27.8	0.54	0	0	-0.96	-0.34	0.99	0	0
17	1483094488400	27.8	0.55	0	0	-0.96	-0.34	0.99	0	0
18	1483094488500	27.8	0.53	0	0	-0.96	-0.34	0.99	0	0
19	1483094488600	27.8	0.56	0	0	-0.96	-0.34	0.99	0	0
20	1483094488700	27.8	0.61	0	0	-0.96	-0.34	0.99	0	0

Figure 11: Test 2, first 20 data collected during the test

N.	time	battery (V)	current (A)	Linear speed (m/s)	Rotational speed (rad/s)	X	Y	H	Tool speed (rpm)	Tool Current (A)
8938	1483095380500	27.4	0.84	0	-0.07	-1.02	1.04	-0.38	0	0
8939	1483095380600	27.2	2.33	0	-0.07	-1.02	1.04	-0.38	0	0
8940	1483095380700	27.3	1.1	0	-0.05	-1.02	1.04	-0.38	0	0
8941	1483095380800	27.3	0.97	0	-0.02	-1.02	1.04	-0.44	0	0
8942	1483095380900	27.3	1.16	0	-0.02	-1.02	1.04	-0.44	0.54	0
8943	1483095381000	27.3	1.32	0.02	0	-1.02	1.04	-0.44	3.8	0.01
8944	1483095381100	27.2	2.29	0.03	0	-1.02	1.04	-0.44	5.71	0.08
8945	1483095381200	26.9	3.21	0.03	-0.02	-1.02	1.04	-0.44	7.07	0.45
8946	1483095381300	26.8	3.77	0.04	-0.02	-1.01	1.04	-0.46	11.41	0.99
8947	1483095381400	26.7	4.2	0.05	-0.03	-1.01	1.04	-0.46	15.76	1.62
8948	1483095381500	26.7	4.41	0.05	-0.04	-1.01	1.04	-0.46	19.84	2.03
8949	1483095381600	26.7	4.58	0.05	-0.05	-1.01	1.04	-0.46	22.55	2.29
8950	1483095381700	26.7	4.5	0.05	-0.05	-1.01	1.04	-0.46	24.73	2.55
8951	1483095381800	26.5	5.98	0.05	-0.05	-1.01	1.04	-0.46	26.09	2.75
8952	1483095381900	26.7	4.23	0.05	-0.06	-0.98	1.03	-0.5	27.17	2.8
8953	1483095382000	26.8	4.03	0.05	-0.03	-0.98	1.03	-0.5	28.53	2.88
8954	1483095382100	27.2	1.28	0.05	-0.02	-0.98	1.03	-0.5	19.02	1.12
8955	1483095382200	27.3	1.19	0.03	-0.02	-0.98	1.03	-0.5	-12.5	0.02
8956	1483095382300	27.3	1.34	0.02	-0.01	-0.98	1.03	-0.5	0.27	0.01
8957	1483095382400	27.2	1.81	0.01	0	-0.98	1.03	-0.5	0	0.01

Figure 12: Test 2, last 20 data collected during the test

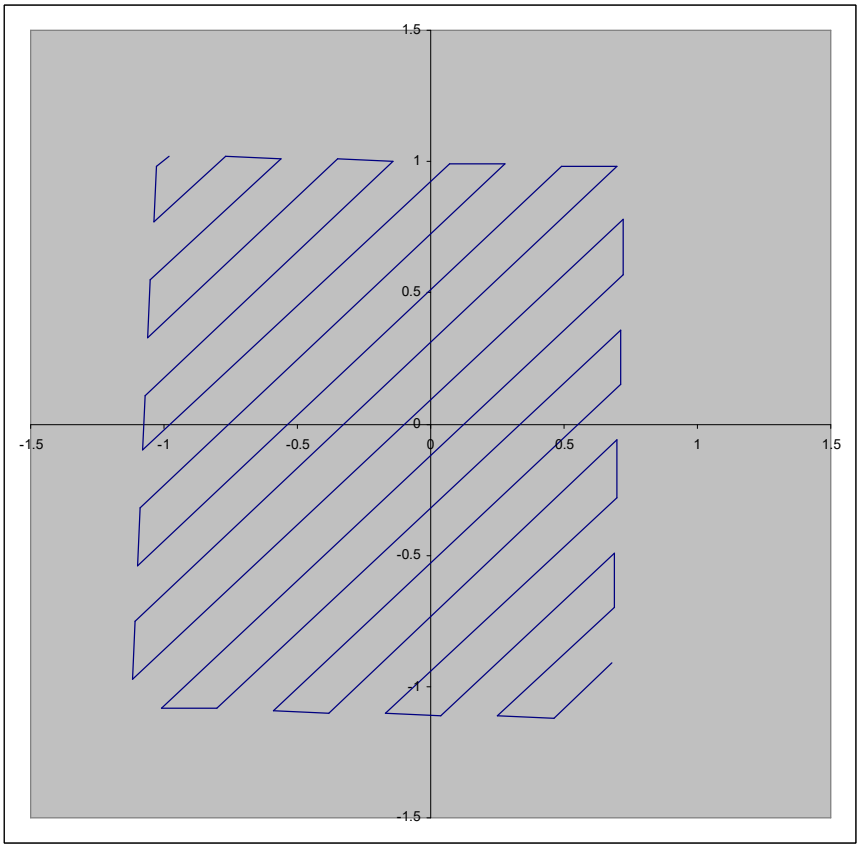


Figure 13: Test 2, trajectory planned by the path planner

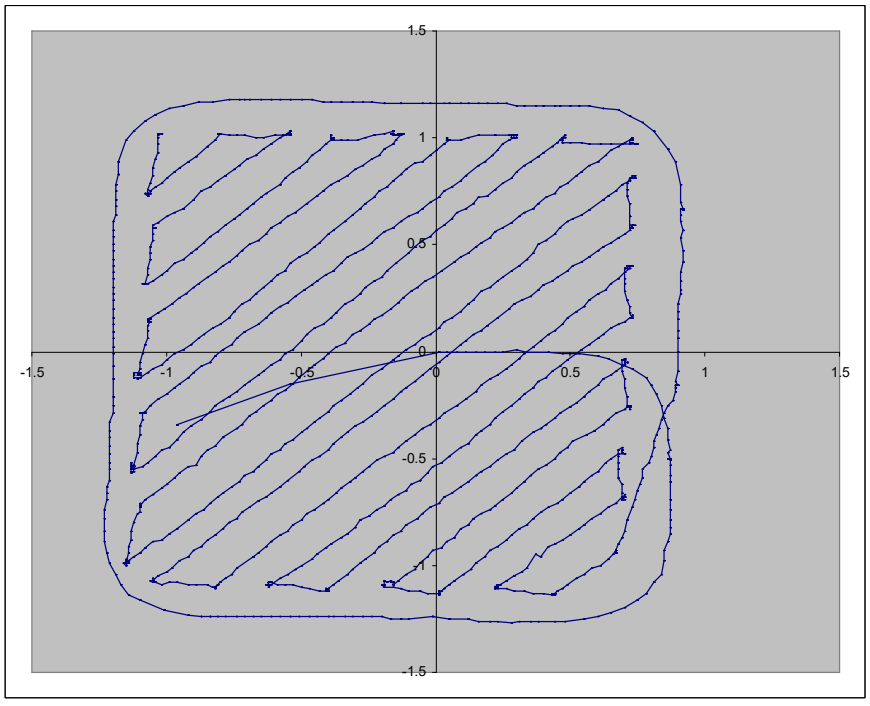


Figure 14: Test 2, trajectory followed by the robot

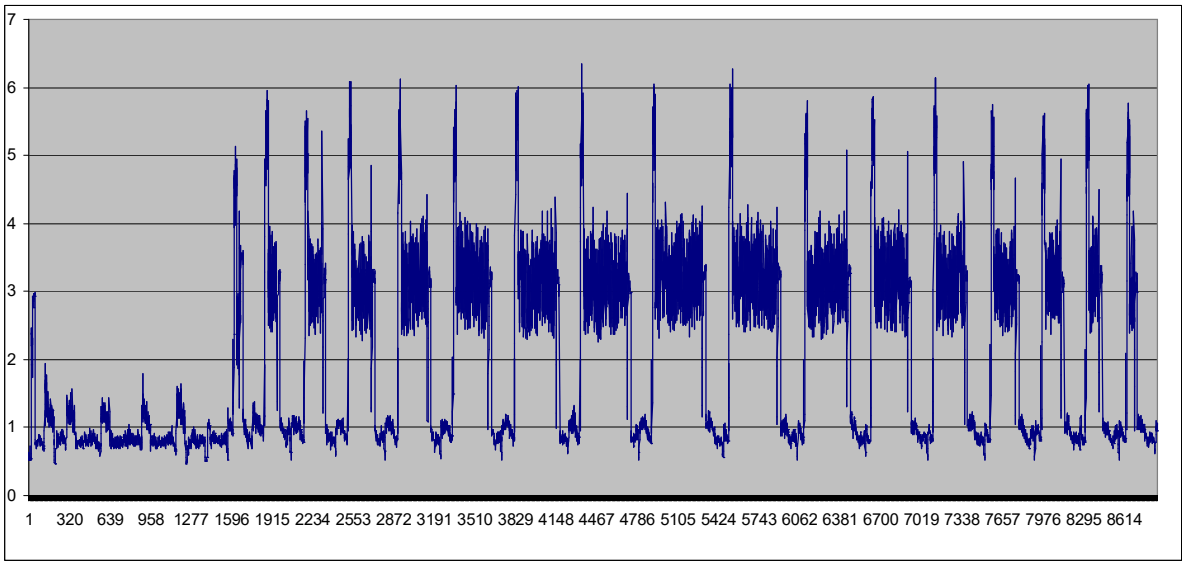


Figure 15: Test 2, current

Parameter	Value
area dimension	2.70 m 3.0 m = 8. 1 m^2
dimension of cleaned area	6.48 m^2
effectiveness	6.48 / 8.1 = 80.01%
cleaning time	14.78 min
productivity	6.48 / 14.78 x 60 = 26.31 m^2/h
average speed	0.05 m/s
battery nominal voltage	25.9 V
battery nominal Ah	13.8
average current consumption	2.07 A
max current	6.35 A
battery run time	13.8 / 2.07 = 6.66 h
Wh per consumption	2.07 x 25.9 = 53.69 Wh

Figure 16: Test 2, performance during a test

3.3 Result of Test 3

N.	time	battery (V)	current (A)	Linear speed (m/s)	Rotational speed (rad/s)	X	Y	H	Tool speed (rpm)	Tool Current (A)
1	1483097211995	27	1.4	0	0	0.01	0	0	1.9	0
2	1483097212095	27	1.64	0.01	-0.02	0.01	0	0	4.89	0.01
3	1483097212195	26.7	3.87	0.03	0	0.01	0.01	0	5.98	0.01
4	1483097212295	26.6	3.87	0.04	-0.01	0.01	0.01	0	8.97	0.2
5	1483097212395	26.5	4.6	0.04	-0.03	0.01	0.01	0	12.77	0.69
6	1483097212495	26.3	5.75	0.05	-0.03	0.01	0.01	0	17.12	1.41
7	1483097212595	26.3	5	0.06	-0.02	0.01	0.01	0	20.38	2.04
8	1483097212695	26.4	4.85	0.06	-0.01	0.01	0.01	0	23.91	2.42
9	1483097212795	26.3	5.66	0.07	-0.01	0.04	0.01	-0.02	25.54	2.53
10	1483097212895	26.2	6.08	0.07	-0.01	0.04	0.01	-0.02	27.45	2.67
11	1483097212995	26.3	6.14	0.07	-0.01	0.04	0.01	-0.02	27.72	2.73
12	1483097213095	26.3	5.55	0.07	-0.01	0.04	0.01	-0.02	29.08	2.79
13	1483097213195	26.4	5.12	0.07	0	0.04	0.01	-0.02	29.08	2.75
14	1483097213295	26.3	5.26	0.07	0	0.07	0	-0.03	29.08	2.84
15	1483097213395	26.3	4.69	0.07	0.01	0.07	0	-0.03	29.35	2.94
16	1483097213495	26.4	4.95	0.07	0.01	0.07	0	-0.03	30.16	2.88
17	1483097213595	26.3	5.45	0.07	0.01	0.07	0	-0.03	30.71	2.74
18	1483097213695	26.3	5.59	0.07	0.01	0.07	0	-0.03	30.16	2.65
19	1483097213795	26.3	5.13	0.07	0.01	0.07	0	-0.03	29.62	2.67
20	1483097213895	26.3	5.4	0.07	0.01	0.11	0	-0.03	29.89	2.72

Figure 17: Test 3, first 20 data collected during the test

N.	time	battery (V)	current (A)	Linear speed (m/s)	Rotational speed (rad/s)	X	Y	H	Tool speed (rpm)	Tool Current (A)
8246	1483098032595	26.4	2.58	0	0	0.02	-1.05	3.1	0	0
8247	1483098032695	26.4	2.61	0	0	0.02	-1.05	3.1	0	0
8248	1483098032795	26.4	2.61	0	0	0.02	-1.05	3.1	0	0
8249	1483098032895	26.4	2.6	0	0	0.02	-1.05	3.1	0	0
8250	1483098032995	26.4	2.62	0	0	0.02	-1.05	3.1	0	0
8251	1483098033095	26.4	2.77	0	0	0.02	-1.05	3.1	0	0
8252	1483098033195	26.4	2.62	0	0	0.02	-1.05	3.1	0	0
8253	1483098033295	26.4	2.59	0	0	0.02	-1.05	3.1	0	0
8254	1483098033395	26.4	2.57	0	0	0.02	-1.05	3.1	0	0
8255	1483098033495	26.4	2.57	0	0	0.02	-1.05	3.1	0	0
8256	1483098033595	26.4	2.56	0	0	0.02	-1.05	3.1	0	0
8257	1483098033695	26.4	2.56	0	0	0.02	-1.06	3.1	0	0
8258	1483098033795	26.4	2.56	0	0	0.02	-1.06	3.1	0	0
8259	1483098033895	26.4	2.56	0	0	0.02	-1.06	3.1	0	0
8260	1483098033995	26.4	2.54	0	0	0.02	-1.06	3.1	0	0
8261	1483098034095	26.4	2.54	0	0	0.02	-1.06	3.1	0	0
8262	1483098034195	26.7	0.48	0	0	0.02	-1.06	3.1	0	0
8263	1483098034295	26.7	0.48	0	0	0.02	-1.06	3.1	0	0
8264	1483098034395	26.8	0.48	0	0	0.02	-1.05	3.1	0	0
8265	1483098034495	26.8	0.47	0	0	0.02	-1.05	3.1	0	0

Figure 18: Test 3, last 20 data collected during the test

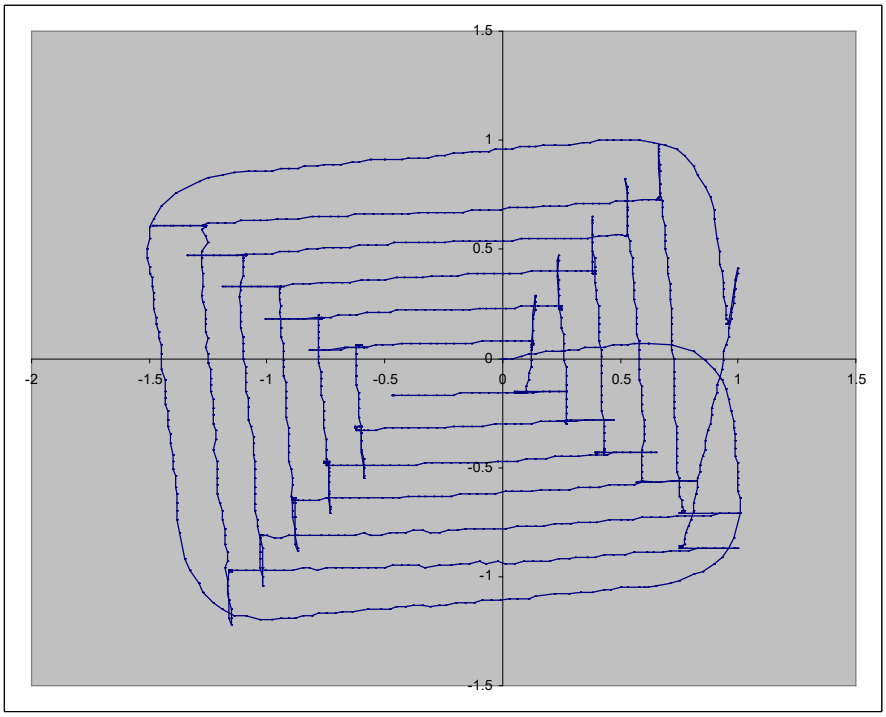


Figure 19: Test 3, trajectory planned by the path planner

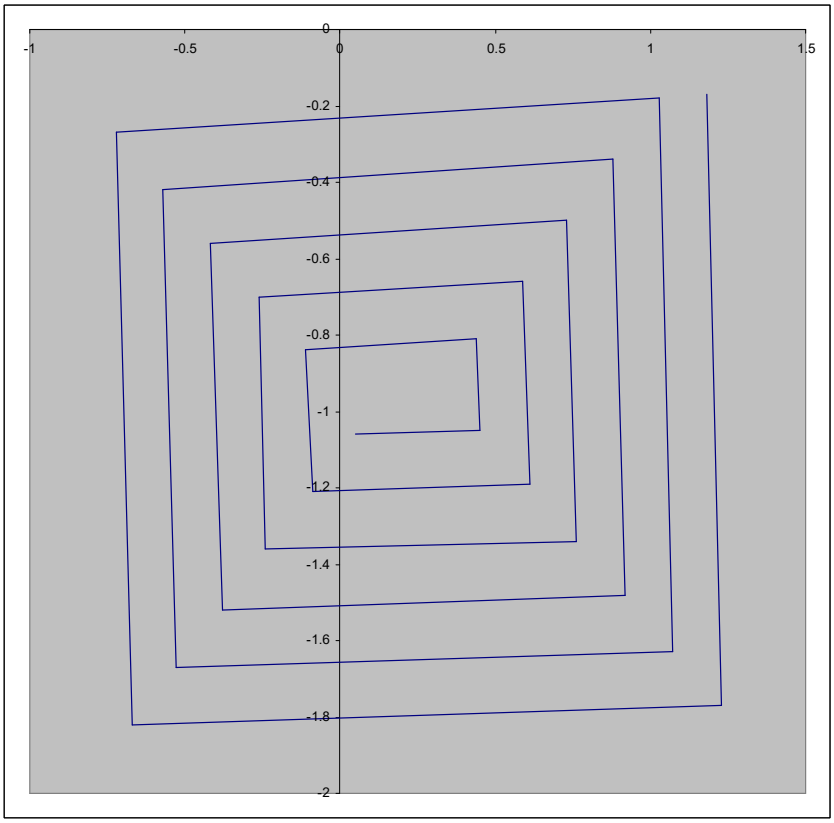


Figure 20: Test 3, trajectory followed by the robot

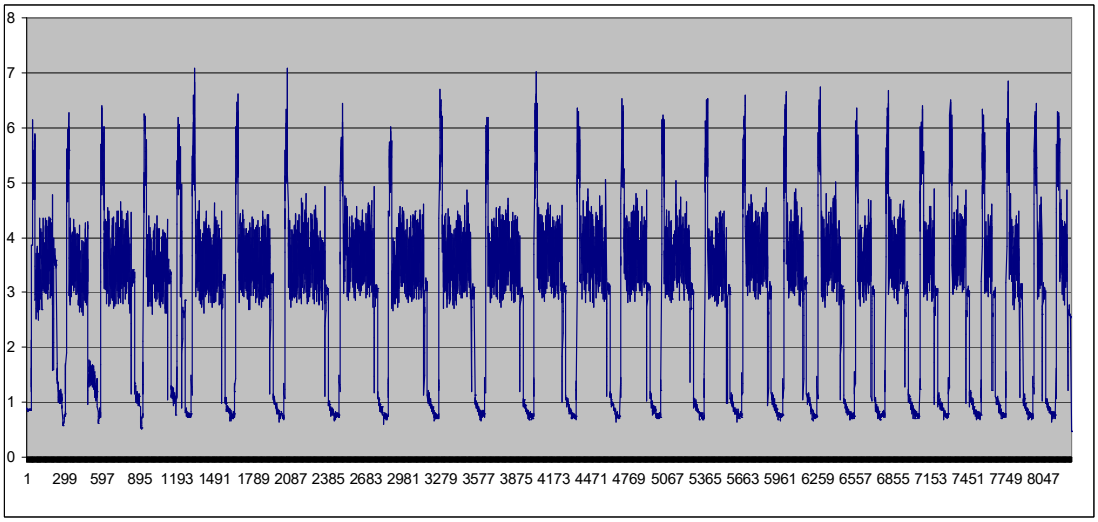


Figure 21: Test 3, current

Parameter	Value
area dimension	2.70 m 3.0 m = 8. 1 m^2
dimension of cleaned area	6.61 m^2
effectiveness	6.61 / 8.1 = 82.01%
cleaning time	13.78 min
productivity	6.61 / 13.78 x 60 = 28.78 m^2/h
average speed	0.05 m/s
battery nominal voltage	25.9 V
battery nominal Ah	13.8
average current consumption	2.94 A
max current	7.09 A
battery run time	13.8 / 2.94 = 7.70 h
Wh per consumption	2.94 x 25.9 = 76.02 Wh

Figure 22: Test 3, performance during a test

3.4 Summary of results

Parameter	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Results
area length (m)	3.15	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	
area width (m)	2.70	2.70	2.70	2.70	2.70	2.70	2.70	2.10	2.10	2.10	
area dimension (m^2)	8.51	8.10	8.10	8.10	8.10	8.10	8.10	6.30	6.30	6.30	
dimension of cleaned area (m^2)	6.84	6.48	6.48	6.61	6.61	6.61	6.61	4.97	4.89	5.01	
cleaning time (min)	13.60	13.99	14.78	13.78	13.36	14.86	14.29	10.72	10.58	10.21	
Effectiveness (%)	80%	80%	80%	82%	82%	82%	82%	79%	78%	80%	**80%**
Productivity (m^2/h)	30.18	27.79	26.31	28.78	29.67	26.67	27.75	27.81	27.73	29.44	**28.21**
average speed (m/s)	0.05	0.04	0.05	0.04	0.04	0.05	0.04	0.04	0.04	0.04	**0.04**
average current consumption (A)	3.21	2.46	2.07	2.94	3.19	2.25	2.95	2.64	3.01	3.12	**2.78**
max current (A)	4.93	5.78	6.35	7.09	7.14	6.44	7.03	6.81	7.05	6.95	**7.14**
battery run time (h)	4.25	5.61	6.66	4.70	4.32	6.15	4.68	5.23	4.58	4.42	**5.06**

4 Technical specifications

2F Flooring Fellow Specifications	
Dimensions (l x w x h)	725 x 430 x 410 cm
Weight	Robot: 25 kg Bucket: 1.75 kg Tool: 10 kg Battery: 3.75 kg Total 40.5 kg
Speed	Typical: 0.07 m/s – Max: 0.25 m/s
Tool Speed	Typical: 25 rpm - Max 35 rpm
Productivity	30 m^2/h
Effectiveness	80%
Track Actuation	2 x Fullin FL42RBL 64, 24V Brushless Motor
Tool Actuation	Fullin FL42RBL 64, 24V Brushless Motor, Reduction gear 92:1
Tool motor	Hella 6NW 009 424-791, 12V DC motor
Pump	PMT 30-SA-3.8x7-24VDC-PL, 24V DC motor, 700 ml per min
Laser scan	Hokuyo URG-04LX-UG01
Camera	ELP-USB130W01MT

Power	24V, Standby: 0.5A - Typical: 3.5A - Max 5A
Batteries	25.9 VDC Li-ion battery, 357 Wh, 13.8 Ah
Battery runtime	About 5h, Recharging time: about 2 hours
Water bucket dimension	About 5 L
Tool water bucket dimension	About 20 L
CPU	Intel Core i3-5250U processor 1.3 GHz up to 2.7 GHz dual core
Operative System	Ubunu 14.04
ROS Version	ROS Hydro