Rules for RobotAtFactory 4.0

Festival Nacional de Robótica
Portuguese Robotics Open

Porto, November 2021

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1 Introduction

This competition aims to present a problem inspired on the deployment of autonomous mobile robots on a factory shop floor. One or more robots should be able to transport materials between warehouses or machines that process those materials. The robots must collect, transport and position the materials, self-localize and navigate while avoiding collisions with walls.

The floor is built on a two-sheet A0 print, where ArUco tags on a white background can be used for robot localization. In the first round it is necessary to move the boxes between the incoming and outgoing warehouses. In the second round some boxes must be processed by machines and in the third round some boxes will have to go through two processing machines. The goal will be to transport as many boxes as possible in the shortest time. The different boxes can be recognized by the robot through an ArUco tag placed on the top. Important files can be found at:
`https://github.com/P33a/RobotAtFactory`.

All dimensions given herein, unless otherwise indicated, assume a tolerance of $\pm 5\,\%$.

2 The Robot

Each robot must fit into a rectangle with 30×30 cm and a maximum height of 30 cm. The robot must be completely autonomous and cannot establish any kind of communication with an external system that is not explicitly provided by the organization.

3 The Shop Floor

The competition area simulates a factory floor where there are warehouses and machinery. The maximum dimensions of this area are $1.7 \times 1.2\,\text{m}$. There are four machines available and two warehouses, one of which is used as the source of parts to be produced (the incoming warehouse) and the other is their final destination (the outgoing warehouse). The competition area is presented in figure 3.1.

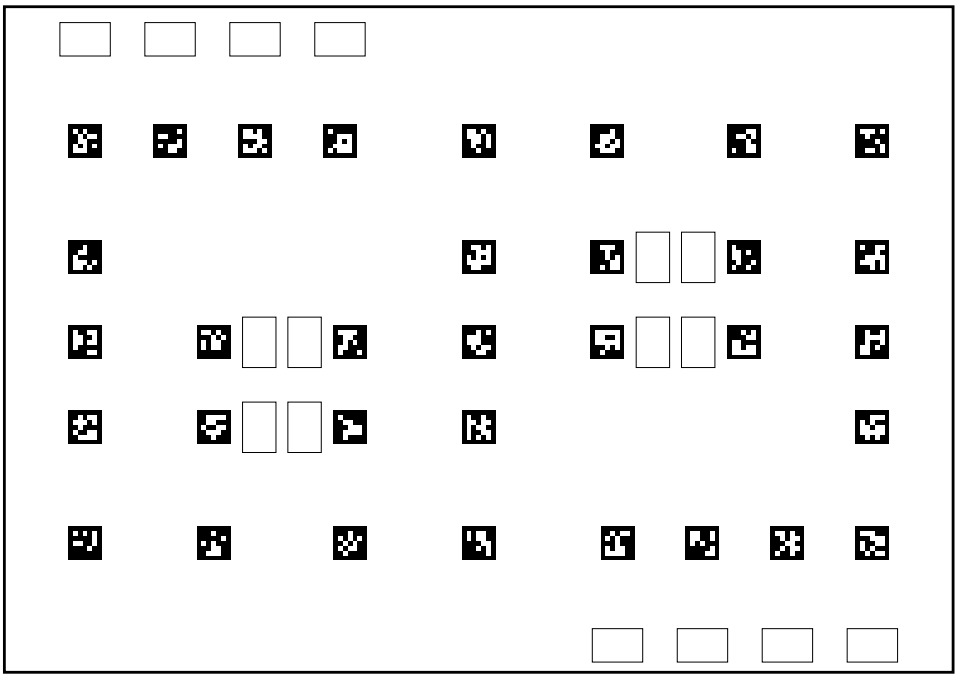

Figure 3.1: Competition area.

The ArUco marker ID can be found on figure 3.2. The markers can be created online[1] with Dictionary 5x5 (50,100,250,1000) and marker size of 60 mm.

[1] `https://chev.me/arucogen/`

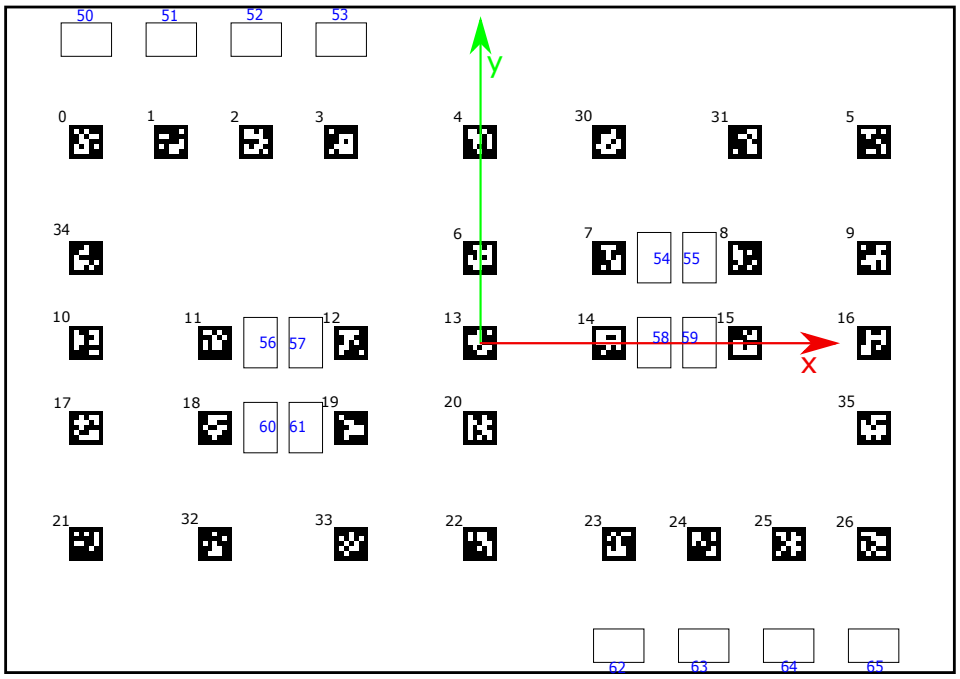

Figure 3.2: Competition area with ArUco IDs (Black - placed on the floor in horizontal direction; Blue - placed vertical in the wall). See Figure 3.3 for example

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In each warehouse or machines there will be markers according to figure 3.3.

The Table 3.1 shows the position and orientation for each marker placed on the floor whereas Table 3.2 shows the position and orientation for each marker placed on the wall (warehouses and machines).

Marker ID	X (mm)	Y (mm)
0	-695	355
1	-545	355
2	-395	355
3	-245	355
4	0	355
5	695	355
6	0	150
7	227	150
8	468	150
9	695	150
10	-695	0
11	-468	0
12	-227	0
13	0	0
14	227	0
15	468	0
16	695	0
17	-695	-150
18	-468	-150
19	-227	-150
20	0	-150
21	-695	-355
22	0	-355
23	245	-355
24	395	-355
25	545	-355
26	695	-355
30	227	355
31	468	355
32	-468	-355
33	-227	-355
34	-695	150
35	695	-150

Table 3.1: Positions and orientation for each ArUco marker on the floor

Marker ID	X (mm)	Y (mm)	Z	RotX	RotY	RotZ
50	-695	565	100	90	0	0
51	-545	565	100	90	0	0
52	-395	565	100	90	0	0
53	-245	565	100	90	0	0
54	338	355	100	0	-90	-90
55	358	355	100	0	90	90
56	-357.5	0	100	0	-90	-90
57	-337.5	0	100	0	90	90
58	337.5	0	100	0	-90	-90
59	357.5	0	100	0	90	90
60	-357.5	-150	100	0	-90	-90
61	-337.5	-150	100	0	90	90
62	245	-565	100	-90	0	180
63	395	-565	100	-90	0	180
64	545	-565	100	-90	0	180
65	695	-565	100	-90	0	180

Table 3.2: Positions and orientation for each ArUco marker on the wall behind part. Rotations are done in a fixed frame, first in Z, then in Y and finally in X.

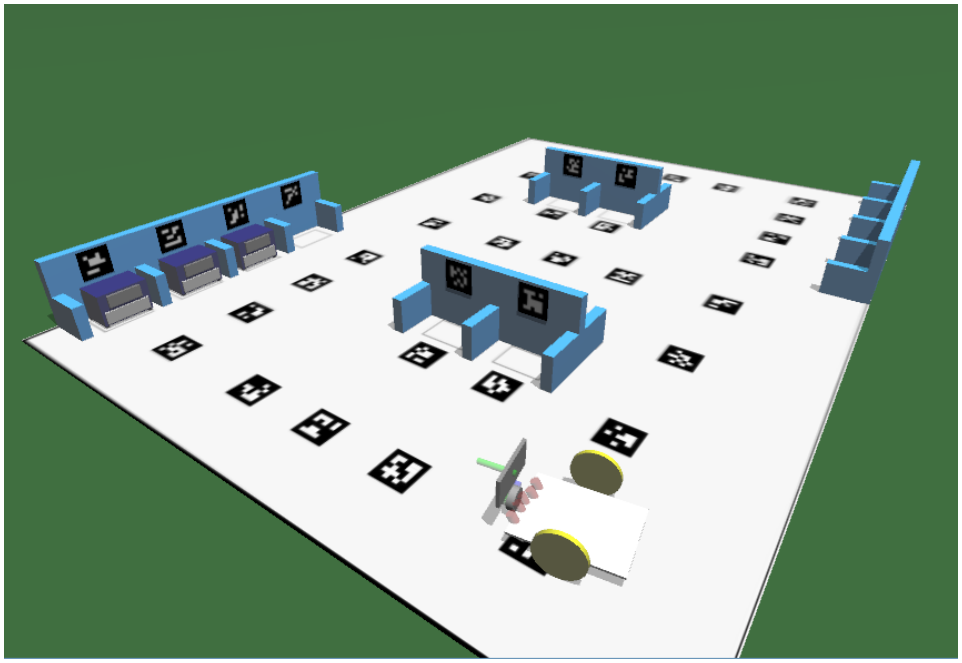

Figure 3.3: Virtual view of the Warehouse ArUco markers.

4 The Machines and the Warehouses

On each machine there is an area where the parts should be placed to be processed (Input) and another one where the processed parts should be picked (Output) as illustrated in figure 4.1. It is the robot's responsibility the loading and unloading of the parts into the machines. After the part is placed on the left side of the machine (Input), it will be processed and should be picked on the right side (Output).

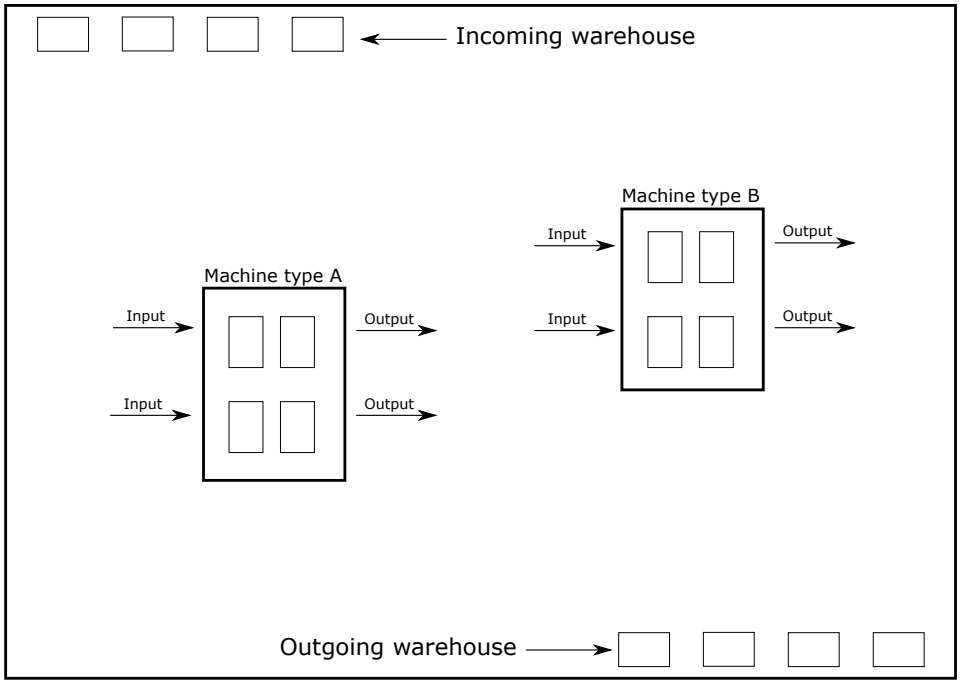

Figure 4.1: Machines and warehouses direction.

5 The Parts

The parts to be transported by the robots have standard dimensions, the width and length of 90 x 60 mm, its height will be no less than 65 mm. There is a metal plate with 20 x 80 mm placed in the box front wall (see figures 5.1 and 5.2). When a part is placed in a machine, the part is transformed in another part type. The delay (or its statistical distribution) for each part/machine will be available to the teams, before the competition begins. There will be a maximum of three different part types, as presented in the next table:

Type	**Tag**
Final Part	Blue
Intermediate Part	Green
Raw Part	Red

Parts Details:

- Weigth: to be defined
- Color: Any color
- Height: 60 mm + 5 mm for the feet
- Width: 90 mm
- Depth: 60 mm
- ArUco Tag: 60 x 60 mm

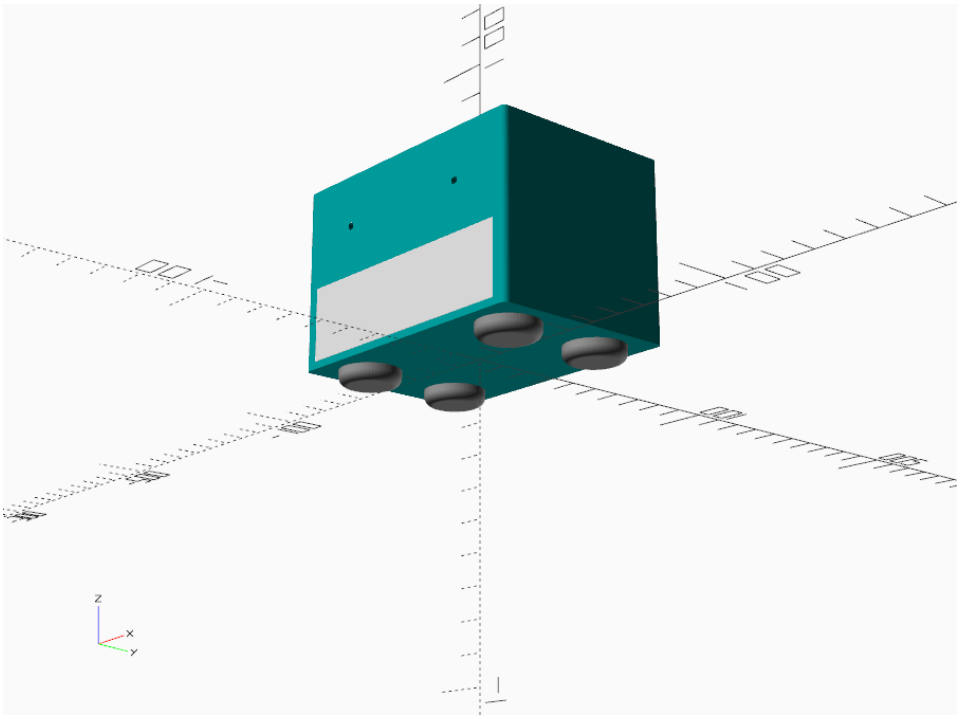

Figure 5.1: Parts.

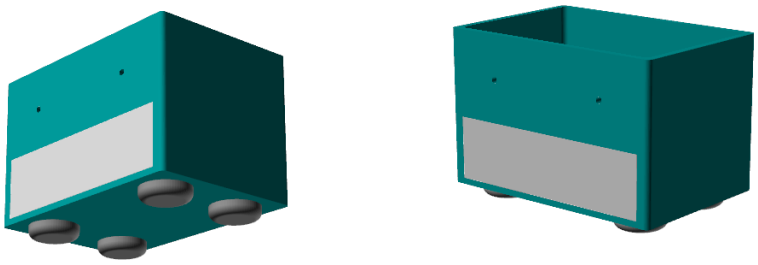

Figure 5.2: Parts.

6 Task Assignment Server

A Wi-Fi server that informs the robot about the parts types will be available after the start of each run. The robot can repeat this request.

Current protocol description:

- The robot must send an UDP packet to the server asking the incoming (outgoing) warehouse parts information with the string: "IWP" ("OWP"); The server will send an UDP packet to the robot with the part types (initial type letters). As example of one configuration where the parts are Blue, Green, Green, Red: "BGGR";
- The robot can send an UDP packet to the server asking the Machine Type A(B) parts information with the string: "MAP"("MBP); The server will send an UDP packet to the robot with the part types (initial type letters) present in the machine, An "X" indicates that the slot is empty. As example of one case where there a Blue part in the upper left corner (1) and a Green part in the lower right corner: "BXXG";

1	2
3	4

- In the case of a request before the run is started, the server information may be unreliable.
- The robot can send an UDP packet to the server with the string: "PING" to check the connection. The Server should answer with "PONG".

7 The Floor Markers

On the shop floor there are no guiding lines. There are ArUco tags that can be used by the robots to find their location. Of course other guidance and localization schemes can be used by the teams. Four areas are set aside, near the corners of the "factory", where the teams can place their own markers to assist the robots in their localization or navigation. These areas are squares with 10 cm sides and the maximum height is 50 cm.

8 The Competition

The competition is divided into three rounds, preferably held on consecutive days. Each team will have 10 minutes to do the initial tests on the field before the trial starts. During the trial a team can attempt as much runs as it is possible in its 10 minutes slot.

For each trial, the final score is the total number of parts correctly placed in the outgoing warehouse. The best run is automatically considered. The time to finish plus any additional time penalization is used as the next criteria. The figure 8.1 shows the starting area for the robot and the machines types with the input and output places. For each run the robot must start inside the green area.

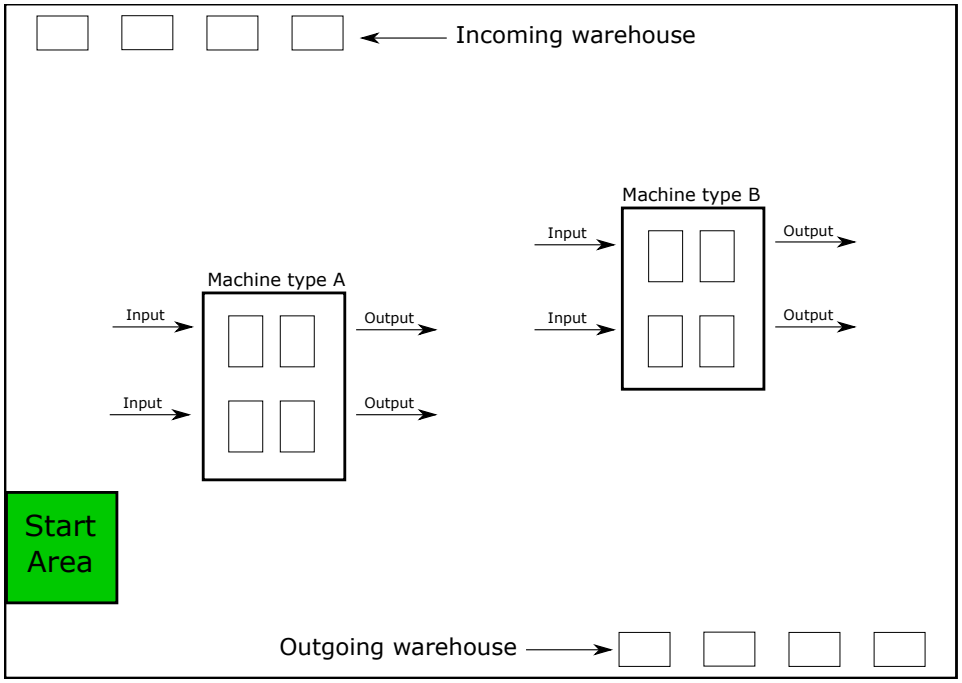

Figure 8.1: Starting area.

8.1 First round

In the first round the objective is just to collect the four parts from the incoming warehouse and transport them to the outgoing warehouse as fast as possible. The four parts will be already placed on the incoming warehouse, ready to be moved.

8.2 Second round

In the second round, some of the four parts present in the incoming warehouse must be placed in a machine for processing. After the completion of this operation they can be carried into the outgoing warehouse.

For this round there is an additional rule that every attempt must be spaced by at least one minute. Is only possible to resume an attempt one minute after the moment when the previous attempt was initiated. This limits the maximum number of attempts to less than 10.

8.3 Third round

In the third round, some parts in the incoming warehouse should be placed sequentially in more than one machine to be completely processed. Because of this there will be three types of parts in play:

Type	**Where it should be placed**
Final Part	Outgoing warehouse
Intermediate Part	Machine type B
Raw Part	Machine type A

For this round there is an additional rule that every attempt must be spaced by at least one minute. Is only possible to resume an attempt one minute after the moment when the previous attempt was initiated. This limits the maximum number of attempts to less than 10.

8.4 Solving problems with the robot during the race

If at any time a team considers that the robot is in a situation which does not expect to be able to recover, the team may ask to stop the run and access to the robot. During the intervention on the robot, the time does not stop. To start another run, the team must position the robot, ask the referee permission and when it is given may restart the robot. After the team asks for permission to restart the referee must reposition any random element so that information is not available to the robot operator. After asking permission to restart, the team must only restart the robot, further tweaks are not allowed.

8.5 Closed Park

Fifteen minutes before the start of each round the robots must be placed in the closed park, preventing teams from having access to the robot until a predefined period before the start of their trial. During this period, the team must have full access to the field. After that time, which is signalled by the referees, the team must prepare the robot to start its trial.

8.6 Final Classification

The team with the highest total number of parts correctly placed on the outgoing warehouse or a machine is the winner. If there are teams with the same total number of correctly placed parts, the team that took less time to achieve that has the advantage. The total time is calculated using the team's best run for each round.

9 Jury, Referee and time keeping

9.1 Jury

The jury is the maximum authority in the interpretation and application of the herein defined rules or in every deliberation regarding issues that may be missing from them. Its mission is to verify the compliance of the robots with these rules during technical verifications, and support the referee, during the competition, in their audit and enforcement.

Through its authority, the jury ensures justice in the application of rules and regulations.

Decisions of the jury board are final. Appeal from jury decisions is not possible.

The Jury is appointed by the Organizing Committee.

9.2 Referee

The referee ensures the correct application of the competition rules and gives permission, if necessary, for team members to enter the track area during the initial trial tests. The referee may also stop the trial test whenever necessary to dialog and consult the jury.

Regarding any issues that may be missing in these rules the referee must, in all cases, consult the jury.

The referee is appointed by the Organizing Committee.

9.3 Time keeping

Timing keeping is provided by an automatic integrated control system. This system includes two independent clocks: a time totalizer, responsible for measuring the time of the race test, and a time counter responsible for measuring the time of each trial.