

Competição Brasileira de Robotica

RoboCup@Work Brazil 2024
Rulebook

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1 RoboCup@Work Rulebook

This is the first edition of RoboCup@Work Brazil, following the guidelines of the official RoboCup@Work regulations [2]. Adapted to the Brazilian context, it seeks to promote the advancement of industrial robotics and to encourage innovation and collaboration between national teams, maintaining a fair and challenging competition environment.

1.1 Recognition

A thank you to everyone who contributed to the RoboCup@Work community and the robotics industry [1].

1.2 Committee Members

1.2.1 Executive Committee

- Chair: Carlos Cadamuro
E-mail: cadamuro@gmail.com
- General Chair: Danilo Perico
E-mail: daniilo.perico@gmail.com

1.2.2 Technical and Organizing Committee

- Luiza Gonçalves Soares
E-mail: luizagsoaress@gmail.com
- Victor M. O. de Mello Ayres
E-mail: unievayres@fei.edu.br

2 Introduction

2.1 RoboCup@Work Overview

RoboCup@Work aims at the use of robots related to work automation, specifically the development of technologies for the industrial sector. The category seeks to bring new perspectives to service robots and proposes the competition of autonomous mobile robots in a general industrial environment.

Some scenarios related to industrial work include the loading and unloading of objects, such as tools and mechanical parts, the handling, transportation, and organization of these objects, navigation through factory-like environments, and the ability of robots to adapt to sudden changes around them and to overcome obstacles.

2.2 Organization of the League

2.2.1 Executive Committee

Executive Committee (EC) members are responsible for the long term goals of the league and thus have also contact to other leagues as well as to the RoboCup Federation.

2.2.2 Technical Committee

The Technical Committee (TC) is responsible for technical issues of the league, most notably the definition of the rules, such as compliance of the robots with rules and safety standards, the qualification of teams, the adherence to the rules as well as the resolution of any conflicts that may arise during competition.

2.2.3 Organizing Committee

The Organizing Committee (OC) is responsible for all aspects concerning the practical implementation of competition, most notably for providing the competition arenas, ensuring their conformity with the rules, and any objects and facilities required to perform the various tests.

2.3 Team Registration and Qualification

To participate, a team must respond to the Call for Participation (CFP) announced on the @Work mailing list by submitting their Application. Next, they must be selected in the Qualification phase to finally complete their Registration.

2.3.1 Requirements to Participate

Those interested in participating in the CBR – Competição Brasileira de Robótica @Work EL category must form teams of undergraduate or graduate students in any educational institution in any country. Nevertheless, high school students will also be allowed to participate. To register, teams must submit a document describing the development and operation of the robot (TDP) in described format. This TDP will be used for the winners to make a brief report to the other competitors. Please, verify the deadlines on the event website.

2.3.2 Team Description Paper

The Team Description Paper, TDP, describes the team’s primary research, including scientific contributions, objectives, as well as hardware and software descriptions. It must be in Portuguese or English, up to six pages long, and formatted according to the guidelines of the Brazilian Robotics Symposium. All TDPs must be written using the Overleaf TDP template available at [5].

- Name of the team.
- Team members (authors), including the team leader.
- Link to the team web site (optional).
- Promotional video download link (optional).
- Contact information.
- Focus of research/research interest.
- Description of the hardware, including an image of the robot.
- Description of the software, esp. the functional and software architectures.
- Brief explanation of the robot’s safety system.
- Innovative technology (if any).
- Applicability and relevance to industrial tasks.

2.3.3 Promotional Video

The video should clearly demonstrate the robot’s ability to perform the tasks required in the challenge, such as autonomous navigation, picking, and placing. Desired elements include visualizing the sensory capabilities of the robot, i.e., seeing what the robot sees, and the plan currently followed by the robot. Spoken language/an audio stream is not required. Ideal video resolution is 1080p with a 16:9 ratio. It is necessary to provide a link to download the video along with the TDP.

2.3.4 Steps to participate

All teams that intend to participate at the competition have to perform the following steps:

1. Preregistration (all dates are available at CBR website);
2. Submission of qualification material, including a TDP;
3. Final registration (qualified teams only);
4. Payments;
5. Entering the competition.

All dates and concrete procedures will be communicated in due time in advance.

2.3.5 Qualification

The Organizing Committee (OC) will select teams for Qualification. Selections will be primarily based on scientific value, innovations and contributions in the Team Description Paper (TDP).

2.3.6 Registration

Qualified teams can register for the RoboCup@Work competition and must contact the Organizing Committee (OC) to confirm (or cancel) their participation.

Confirmation implies that the team has sufficient resources to complete the registration and participate in the competition. Teams that do not confirm their participation will be disqualified.

3 General Rules

3.1 Robots

The robots used for competition shall satisfy professional quality standards. The concrete definition of these standards is to be assessed by the TC, comprising aspects such as sturdy construction, general safety, and robust operation. Some requirements have to be met to ensure the safety of all participants of the competition. If there are even vague doubts about the eligibility of using particular designs, parts, or mechanisms, the team should consult the TC well in advance.

3.1.1 Design and Constraints

Teams are required to use mobile robots equipped with wheels for movement on flat, firm surfaces; aerial robots are prohibited. Each robot must have at least one manipulator capable of handling specified objects. Robots utilize sensors to gather environmental and object-specific data, ensuring that all sensors comply with safety standards to avoid harm to humans, excluding those classified as laser class 2 or higher.

Size There are no constraints regarding the size and weight of the used robots, but they have to fit in the arena. The minimum passage width is 80cm. The used robots must be able to maneuver in that space.

Electrical The used batteries may not exceed a capacity of 500Wh, and the maximum voltage allowed on the robotic system is 60 V DC.

Movement The robot's maximum speed must not exceed 1.5 m/s at any time during the competition.

Actuator Types Electric, pneumatic, and hydraulic actuation mechanisms are permitted, provided that they are constructed and produced according to professional standards and meet safety constraints. Combustion engines and any kind of explosives are strictly forbidden. Robots may not pollute or harm their environment in any way, e.g. by loss of chemicals or oil, spilling liquids, or exhausting gases.

3.2 Arena

The arena is a static 2D environment composed of walls, tables, obstacles, etc., with a size ranging from at least 10 m² to 120 m². Layouts can include rooms and corridors to create more realistic scenarios, aiming to replicate a factory floor or industrial warehouse. Service Areas mark the locations where robots must perform tasks. Each requested Service Area must be accessible by at least one path that is 80 cm wide. The arenas should feature:

- An area ranging from 10 m² to 120 m²
- A minimum distance of at least 80 cm between elements within the arena
- Service Areas distributed to involve robot movement
- Multiple paths between the Service Areas
- A START and END area

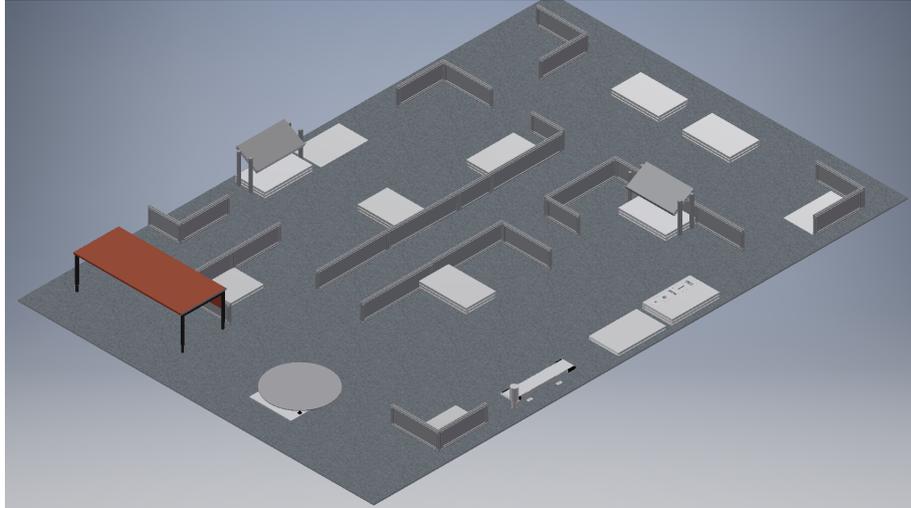


Figura 1: Layout arena RoboCup@Work 2016.

3.3 Floor

The floor should be made of a firm material, such as concrete, wood, plywood, laminated panels, among others. The floors cannot be made of loose or non-firm materials that could damage the operation of the robot's wheels (such as gravel, sand, or carpet). Liquids of any kind are not allowed. The floor may have irregularities of up to 1 cm in any direction (gaps, cracks, elevations, etc.).

3.3.1 Tarpaulin

The arena will be divided into two parts, with one half of the floor covered by a tarp-style carpet. The color may vary depending on local printing, with approximate colors. The printing will be done as for billboards, with a white and semi-gloss background. All tarps have a rubberized surface. This section will have markings to aid navigation as well as markings for the stacking zone section as described in Section 3.6.4.

The tarp will be placed across half of the arena to facilitate navigation with markers on the floor. The other half of the arena will have the same elements arranged differently and without any type of marking. Tasks carried out in this half of the arena will have a 20% bonus. An image of how the tarpaulin would be arranged in the arena can be seen in Figure 2 marked in red. The green line in the drawing represents the start/end line, where the robot must enter and exit the arena.

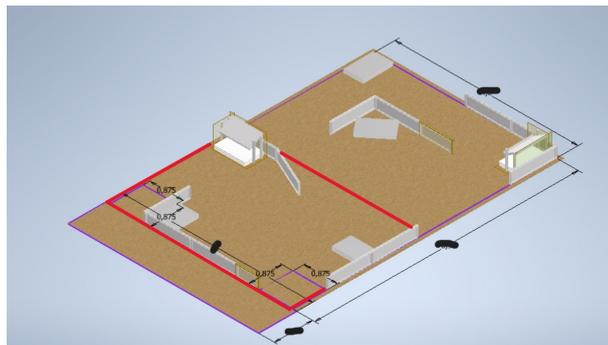


Figura 2: Example of tarpaulin position.

The tarpaulin has markers for easy navigation. These markers do not always comply with all the distance rules between structures cause they are only auxiliary. The tarpaulin is 4m by 2.5m and has all the necessary measures to rebuild this part of the arena, see Figure 3. It is worth mentioning that the other half of the arena has the same parts but without any markings and that the stacking area is only on the tarpaulin. All connections to the tables are in the center with the exception of the table where the ATTCs will be where the landmark is in the top left corner.

3.4 Walls and Virtual Walls

The arena is composed of external and internal Walls used to build structures, create obstacles, or serve as protective barriers for teams and spectators. The Walls can be physical (panels) or virtual (red/white tape with 5cm of width) (Figure4). All walls (physical and virtual) have infinite height. The arena is completely enclosed by Walls (both types are possible), meaning robots are not allowed to exit the arena during a run. All types of Walls will not be altered during the competition. If a robot touches a Wall or Virtual Wall, it will result in a Total Collision. The height of a physical Wall should not be less than 20 cm and not more than 40 cm (but will be considered infinitely high). Most Walls have a uniform main color (white), with some variations possible, but may be reinforced by metal structures. Virtual Walls are made of red/white tape and may never be crossed during a run. The arena may contain Walls and Virtual Walls inside.

3.5 Semi-dynamic Obstacles

In addition to the static elements of the arena, dynamic obstacles can be placed inside the arena before the start of a competition round. The position of these obstacles is decided by the TC during the round preparation phase and is randomized among different types of rounds. The obstacles can be physical or virtual. They may partially or completely block pathways, as long as all active Service Areas remain accessible.

Physical Obstacles measure at least 2cm x 2cm x 20cm (l x w x h) and may be made of any non-transparent, firm material (wood, metal). Some examples are bins, shipping boxes and Wall elements. Their color is not specified. All physical Obstacles are treated like any other arena element during a run, including the rules for collisions (Major Collision).

3.6 Manipulation Zone

The manipulation zone defines the area where Objects can be placed. Thereby, the following constraints need to be satisfied:

- The maximum depth of the manipulation zone from the front of the service area to the end of the manipulation zone is 20cm;
- The minimum distance between Objects to each other is 2cm;
- The minimum distance of the beginning of the manipulation zone to a Wall is 10cm.
- There as an offset of 2cm from the border of the Service Area to the manipulation zone.

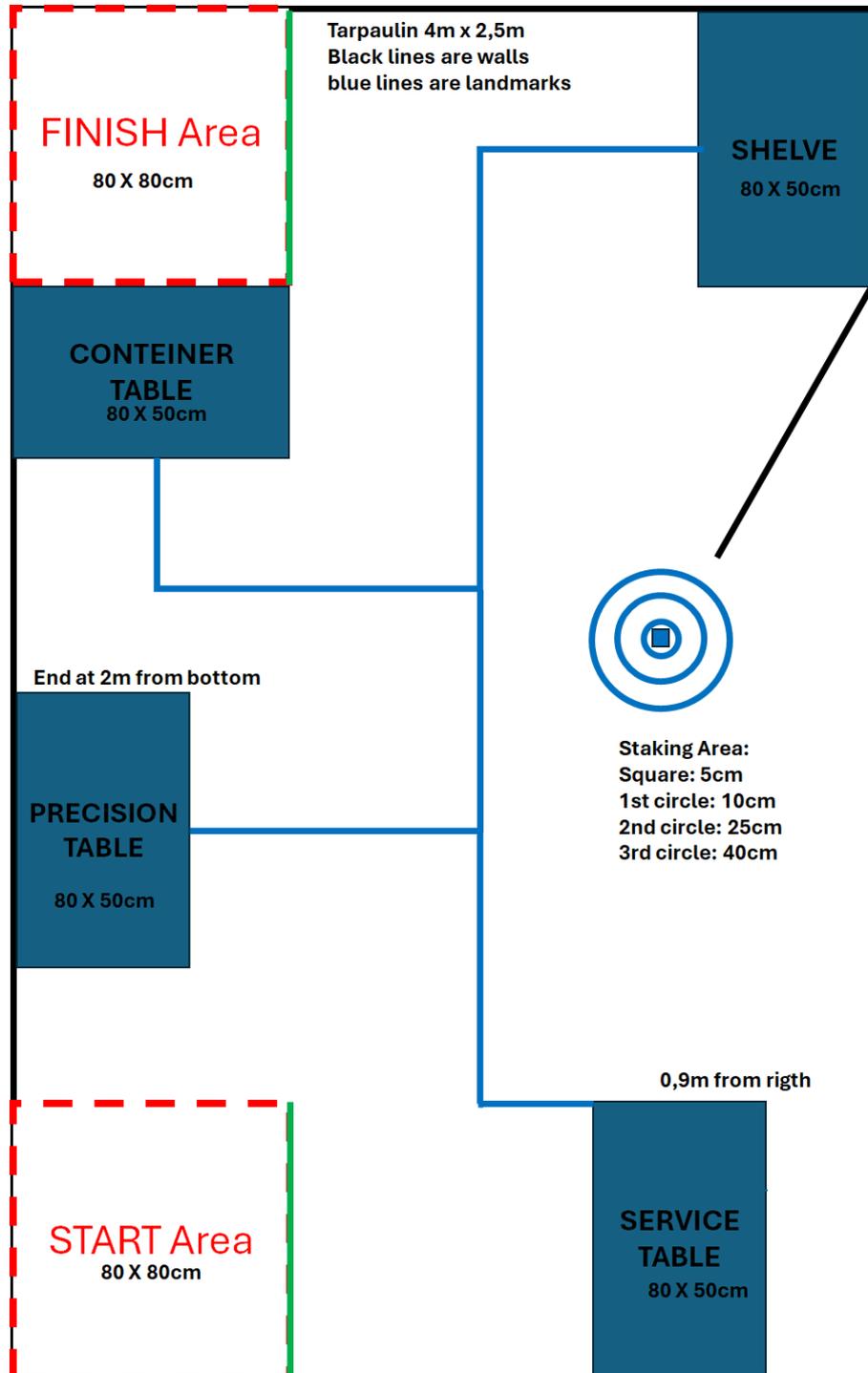


Figura 3: Tarpaulin schematic.



Figura 4: Red/white tape.

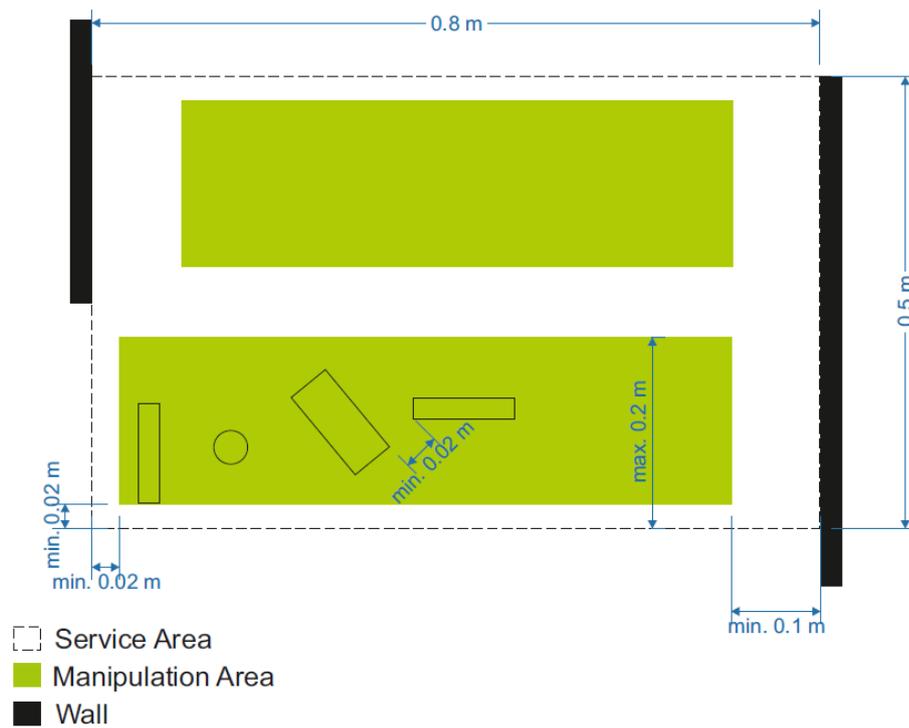


Figura 5: Manipulation zone: the green color indicates the area where Objects can be placed on a Service Area by the referees.

Note, the constraints do not permit, that Objects can be partially occluded dependent on the viewpoint. The manipulation zone also ends up defining the Service Areas, where objects can be manipulated, Figure 5 provides a detailed illustration of how objects can be positioned for a Manipulation Area in a Service Area

3.6.1 Table

The tables can be seen in Figure 6 commonly used have a width of 80cm and a depth of 50cm, with variations of ± 2 cm. In general terms, the table should be large enough to contain at least one manipulation zone. The table heights used are 5cm, 10cm, and 15cm.

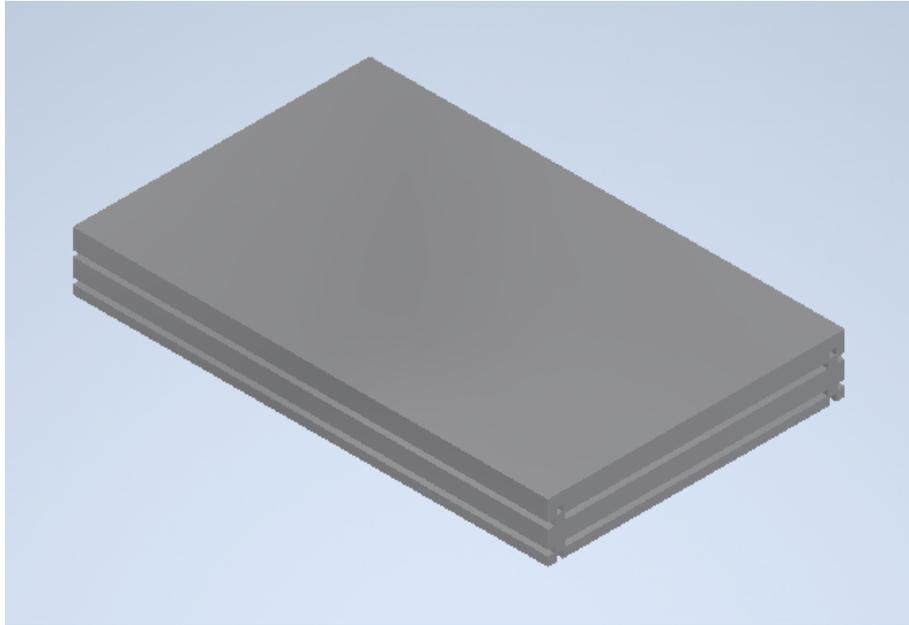


Figura 6: Table.

3.6.2 Shelves

Workstations may contain shelves (Figure 7). The bottom part of the shelf is a table 10 cm high. The maximum height of the shelves should not exceed 40 cm. Therefore, all teams must design their robots to avoid collisions. The top surface of the shelf may be specially designed to serve specific purposes, such as holding objects. The placement of a delivered object must ALWAYS be done on the top shelf.

To make it clearer, the shelf has the shape of the schematic shown in Figure 7. All measurements may vary by up to 5cm.

3.6.3 Precision Placement Tables

The precision placement table as shown in Figure 8 includes object-specific cavities tiles. It is based on a standard 10cm table. For each object used in the test, there will be one specific cavity. The cavity has the dimension of the object plus a 2mm offset for each dimension. At most five cavities are used in the test.

3.6.4 Stacking Zone

The stacking area is a Brazilian difference from the international standard rule. It will be a point marked on the tarpaulin by a blue target where ATTCs must be stacked according to the table presented in the Action Table section. This challenge can only be performed from the marked area of the mat, which forces more advanced teams to work in that part of the arena as well.

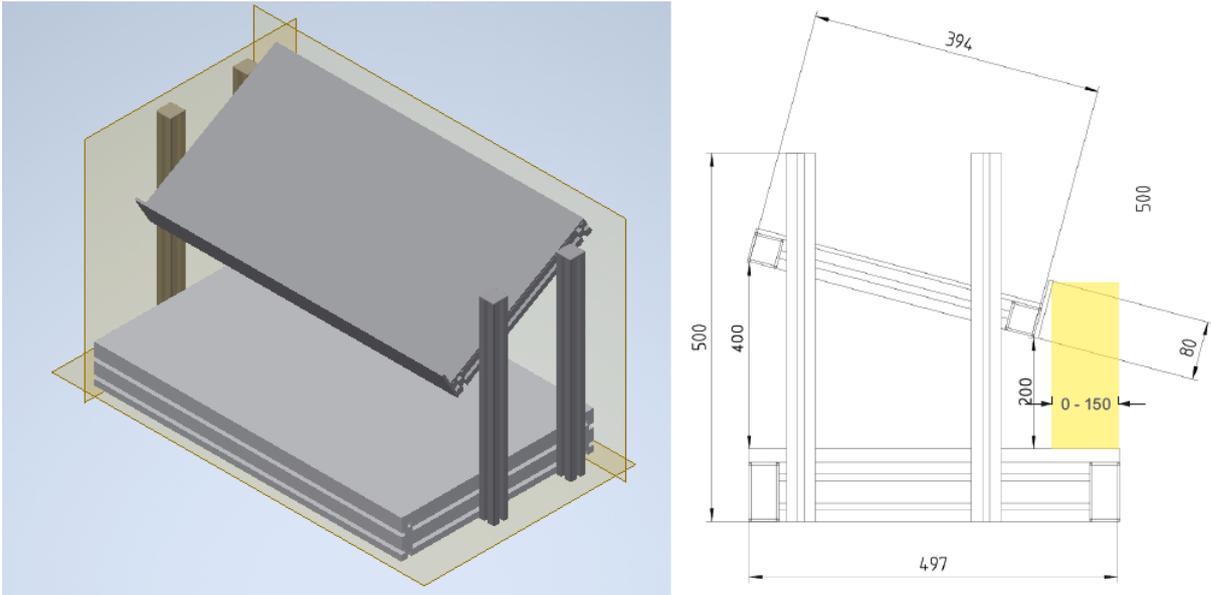


Figura 7: Shelf and its schematic.

3.6.5 Containers

As in many industrial settings, the RoboCup@Work environment may be equipped with several Containers (see Figure 9). The Containers are defined as industrial plastic stacking boxes size 2B, outer dimensions: $135 \times 160 \times 82$ mm, usable dimensions: $120 \times 125 \times 65$ mm in red ca. RAL 3020 and blue ca. RAL 5015. The RAL color definitions are just an example, with the final colors being those available in the competition.

When manipulating ATTCs, the colors MUST be obtained by the robots from the object itself.

3.7 Service Area

A Service Area indicates a location for a robot where tasks (e.g. picking or placing Objects) have to be performed. This location is usually a table, also called a Workstation (WS), but it can be any other structure such as a shelf. To successfully reach a Service Area, robots must position themselves in front of the Service Area in a way that allows manipulation of the Objects of interest. To allow the robots to reach this position, a rectangular area 80cm wide must be kept clear of obstacles.

The arena layout should define where the "front" of a table is. Figure 10 gives an

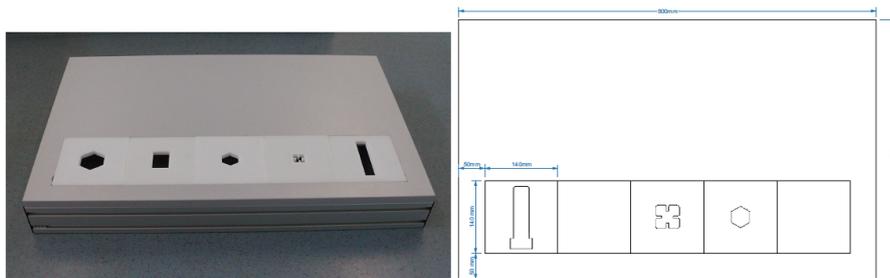


Figura 8: A example of Precision Placement Table.



Figura 9: Containers.

example of what is considered a Service Area or not, where the dashed blue line represents some type of obstacle. The Service Area position only indicates a space and does not specify the robot's direction, which can be chosen by teams according to the individual design of their robots. The Service Table in Figure 3 indicates the Service Area where the April Tag Tagged Cubes (ATTC) will be positioned.

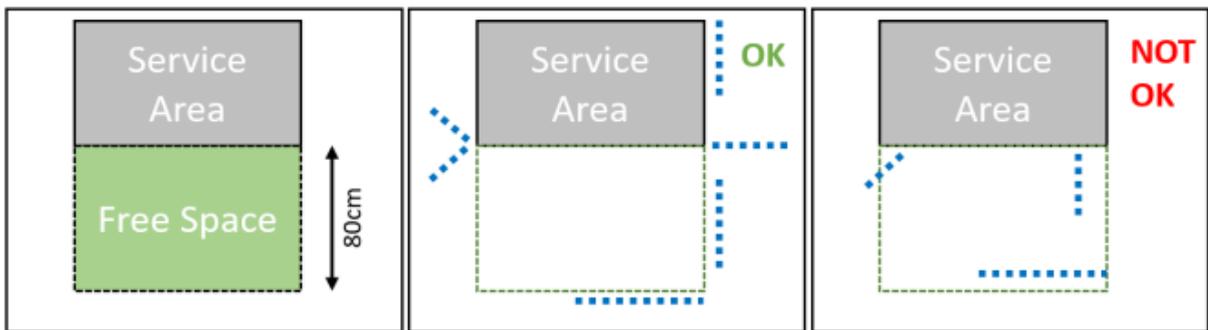


Figura 10: Example of free space in front of Service Areas.

3.8 Objects

The Objects in RoboCup@Work include a wide range of Objects relevant in industrial applications of robotics. They eventually cover any raw material, (semi-)finished parts or products as well as tools and possibly operating materials required for manufacturing processes. Object types are selected by the TC and shall vary in complexity due to different shapes, colors and uses of objects.

Currently there are three sets of Objects used in the competition: Basic, Advanced and April Tagged (ATTCs). The following sections provide details about those sets. The exact appearance of the object used in the competition can slightly vary due to availability, e.g. different coating colors for some standard parts.

3.8.1 Basic object set

The Basic Object Set includes standard profile rails, screws and nuts with various sizes and masses, see Figure 11.

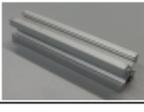
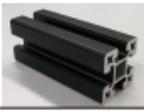
ID	Object	Symbolic Description	Mass	Details
1		F20_20_B	49 g	Small aluminium profile Coating/Colour: black anodized Size: 20 × 20 × 100mm
2		F20_20_G	49 g	Small aluminium profile Coating/Colour: gray anodized Size: 20 × 20 × 100mm
3		S40_40_B	186 g	Large aluminium profile Coating/Colour: black anodized Size: 40 × 40 × 100mm
4		S40_40_G	186 g	Large aluminium profile Coating/Colour: gray anodized Size: 40 × 40 × 100mm
5		M20_100	296 g	Screw ISO4014, DIN 931, EU 24014 Coating/Colour: blank, black burnished Size: M20 × 100
6		M20	56 g	Small nut ISO4032, DIN934, EU 24032 Coating/Color: blank, black burnished Size: M20
7		M30	217 g	Large nut ISO4032, DIN934, EU 24032 Coating/Color: blank, black burnished Size: M30

Figura 11: RoboCup@Work Basic Object Set.

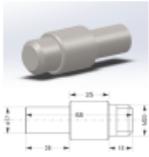
ID	Object	Symbolic Description	Mass	Details
20		Axis2	180 g	Steel axis Misumi: SFUB25-25-F28-P17-T15-S10-Q20 Coating/Colour: blank, black burnished Length: 68 mm Diameter: 17mm, M20 Misumi (visited Januar 2022)
21		Bearing2	100 g	Bearing SKF YAR203-2F Coating/Colour: gray Useable with housing SKF (visited Januar 2022)
22		Housing	60 g	Housing SKF P40 Coating/Colour: gray Useable with bearing Remark: needs two hex socket screw M8x10 (ISO 4762, DIN 912) and two M8 nuts (ISO 4032, DIN 934) SKF (visited Januar 2022)
23		Motor2	350g	Motor 755 Coating/Colour: gray Size: 66.7 × 42.0mm Diameter: $d_{axis} = 5\text{mm}$, $l_{axis} = 10\text{mm}$ Amazon (visited Januar 2022)
24		Spacer		Flanged Spacer Misumi CLJHJ25-30-70 Coating/Colour: white Size: 70mm Diameter: $d_{inner} = 25\text{mm}$, $d_{outer} = 30\text{mm}$ Misumi (visited Januar 2022)

Figura 12: Advanced object parts..

3.8.2 Advanced object set

Since 2022 some more complex objects, Figure 12 have been selected for the category as well as some tools Figure 13, these are called Advanced object sets.

Object	Symbolic Description	Mass	Details
24		Screwdriver	19g WERA 352 Ball end screwdriver, hexagon socket screws Coating/Colour: black/green Size: 181mm Diameter: $d_{tip} = 2.5\text{mm}$ Code: 05138070001 Amazon (visited Januar 2022)
25		Wrench	ca. 72g WERA Jocker 6000, 8mm Ratcheting combination wrenches Coating/Colour: silver/grey/pink Size: ca. 144mm Diameter: $d_{max} = 20\text{mm}$ Code: 05073268001 Amazon (visited Januar 2022)
26		Drill	ca. 10g Bosch Drill HSS-Co DIN338 Drill Coating/Colour: gold/ Cobalt alloy Length: ca. 151mm Diameter: $d_{max} = 13\text{mm}$ Code: 3165140382724 Amazon (visited Januar 2022)
27		AllenKey	ca. 10g Wera Allen Key 8mm, 3950 PKL L-key, metric, stainless Coating/Colour: silver Length: ca. 195mm \times 37mm Diameter: $d_{max} = 8\text{mm}$ Code: 05022708001 Amazon (visited Januar 2022)

Figura 13: Advanced object tools.

3.8.3 April Tag Tagged Cubes (ATTC)

April Tag Tagged Cubes will be used in the competition as an alternative means to identify objects, see Figure 14. When necessary, teams may request the TC (Technical Committee) to replace classic objects with ATTC. ATTCs are 3D printed cubes marked with April tags representing the item ID. They can be of any printable material on standard FDM 3D printers. For this competition, the color of the ATTCs will be red and blue. One example of objects is show in Figure bellow.



Figura 14: Example of objects.

The standard ATTC measures $42\text{mm} \times 42\text{mm} \times 42\text{mm}$ and has slightly rounded edges, like the shape of aluminum profile rails. A 1mm deep cavity measuring $40.5\text{mm} \times 40.5\text{mm}$ is embedded in the top of the cube to make centering the April tag printouts easier, see Figure 15.

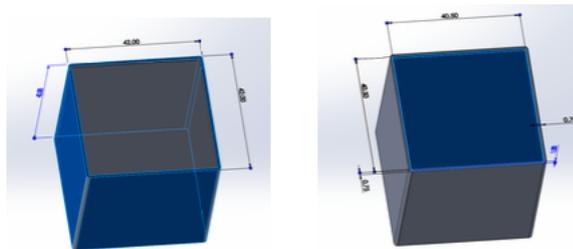


Figura 15: Cube dimensions.

The April Tags measure $40\text{mm} \times 40\text{mm}$, including a 1bit black and 1bit white border as shown in Figure 4. The full set of tags are available at reference [4]. STL files are available at reference [3]. In this link you are able to find an April Tag generator programmed in Python, see a example in Figure 16.

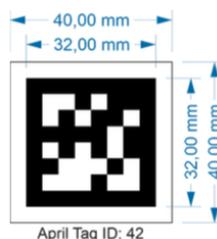


Figura 16: April Tags dimensions.

To allow for the more advanced tests to be performed using the simplified April Tag detection method, the precise placement cavities are marked with a tag. For the precise placement tests, a special PP tile is used which allows a tag to be placed with a constant offset from the hole. The used ID matches the ID of the object that must be placed into that cavity. Only this task will have April Tag identification.

4 Competition

4.1 Team Leader

During registration, each team has to designate a member as the team leader. If it becomes necessary to change the leader, the team must inform the OC of the new leader. The team leader is the only person authorized to officially communicate with the referees during the competition, for example, to request a test, ask for a reset, among other issues during the competition. The team leader may ask the OC to accept additional team members for these tasks.

4.2 Meetings and Language Communication

Both the TC and the OC may organize several special meetings during a competition, such as referee meetings, team leader meetings, etc. The meetings will be planned and announced locally. They are used to clarify rules, assign time slots, request test participation or for any other exchange of information between teams and committee members.

It is the responsibility of each team to inform themselves about the organization and scheduling of such meetings. Each team is expected to send at least one representative to such meetings. If the meeting refers to specific roles, such as 'referee' or 'team leader', the person designated by the team to fill this role is expected to participate.

4.3 Parc Fermé

The parc fermé is an area adjacent to the arena, designed to prevent the passage of people and the movement of objects at all times during the competition. Its main purpose is to serve as a preparation area before the test rounds, where the robots must be aligned as they are drawn for the test. Typically, this area is positioned facing the audience, as it is in the collective interest to showcase the category so that both visitors and members of other teams can observe the RoboCup@Work robots. Robots can be brought to this area manually or by teleoperation, but once in their designated position, they can no longer be operated or adjusted. Preferably, the robot should remain powered on at all times while in the parc fermé. However, if this might hinder its performance due to lack of power, it should be communicated to the referee and the technical committee, and the robot may be turned off. It is also recommended that teams leave the robots with their manipulators if they are already in the starting position.

4.4 Competition Procedure

The competition is conducted in the form of TESTS. A test requires a robot to perform various skills, including navigation, manipulation, task planning, and autonomous decision-making. Each type of test focuses on a specific skill of the robot, which does not mean that other skills will not be evaluated during such tests. For example, in a test where the focus is on object manipulation, there may not be significant changes in navigation; however, if the robot causes a total collision, the test will be interrupted.

A competition session consists of multiple performance stages (one for each team), including a preparation phase, an execution phase, and a final phase.

4.5 Arena Preparation

Fifteen minutes before the start time of the competition sessions, the arena is prepared for the next test. The TC (Technical Committee) is responsible for verifying the position of each static element of the arena, and objects will be placed in the Service Areas. The TC will decide where the dynamic elements of the arena will be positioned. This includes placing arena elements, obstacles, false objects (objects that are not on the object list and therefore cannot be manipulated by the robot), containers, etc.

4.5.1 Preparation Phase

During the prep phase, teams are allowed to move their robot from the parc fermé to the defined start pose in the arena either by hand or by carefully driving manually. They should prepare their robot for their run and can therefore remote access the robot and/or make minor changes. It is explicitly forbidden to hardcode solutions for specific requirements of a test during this phase (e.g. drawing position of obstacles in the map). Also, if the robot passes and detects obstacles during this phase, they must be erased from the memory (e.g. clear costmap) unless they can be detected from the START location. The TC might disqualify teams that try to gain unfair advantages from the current or even the following tests.

4.5.2 Run Phase

The run phase begins once the preparation time is up or when the team leader announces that the team is ready. The task is then sent to the robot and from there on, the robot must act fully autonomously. It is forbidden to interact or control the robot in any human kind (keyboard/mouse actions, gestures, voice). The only interaction allowed is the unplugging of a LAN cable connecting the robot and the controlling pc when relying on wired communication due to onsite WiFi jams. During the run phase, the robot must not leave, nor may any person enter the arena. Team members of the performing team are allowed to enter the arena to prevent damage in case of an error (e.g. remove a dropped object from the robots path), but receive a penalty for each interaction. If a robot behaves uncontrolled and poses a potential threat to the environment, any person may approach the robot and press the emergency stop. However, it is requested and strongly advised that only the developers touch their robot.

The run phase regularly ends when:

- The robot has reached the FINISH location of the arena.
- The run time is up.
- The team leader says 'stop'.
- The robot has caused a second major collision.
- The emergency stop button had to be pressed before a restart call.
- A team was identified to be cheating.

The end of a run phase must be announced by the responsible judge by saying "end". Once this happened, the team may touch and control their robot to make it stop completely.

4.5.3 Restarting a Run

During a run, the team leader can restart the test execution once. Therefore he/she must say 'restart', which stops the current run phase. The robot must be stopped using the emergency switches, which then allows the refs to reset the arena state. The remaining run time will be noted and used after the restart. Once the refs have finished resetting the arena, the performing team is brought back to their prep phase, which allows them to move the robot back to the start area and prepare it for the restarted run. A so called tactical call of a restart (e.g. to prevent a major collision) is allowed, because this rewards the teams knowledge about the robot. Note: When the first major collision occurs, the team can decide whether they stop the run or they restart the run.

4.5.4 End Phase

In the resulting end phase the team is expected to move their robot back to parc fermé. Referees gather and discuss their performance rating afterwards. Once they agree on the performing team's result, the team leader is required to accept this score. Teams are allowed to make their case if they do not agree with the refs decision, but cannot force changes and are expected to be understanding. Special cases will be decided by the TC if the rulebook leaves room for interpretation. Once the score has been accepted by a team, the arena must be set up for the next run if necessary. The prep time of the next team begins once the arena state is declared as ready by all refs.

4.6 Skipping Tests

If a team decides to not participate in a test during the official time slot, they may repeat that test type once in one of the following competition slots. Their performance slot for the later test type is then replaced by one that suits the previously skipped test type, and they then can perform that test type instead of the originally scheduled one. This should enable struggling teams to do the more simpler tests later in the competition, but should only be used by teams if it is really necessary in order to keep the structure of the overall competition. It is not allowed to repeat a test that has been replaced with this option.

5 Tests

5.1 General Rules

- The challenges will be carried out according to their level of difficulty and in the order in which they appear in this document.
- The prep phase has a time limit of 3 minutes.
- Teams must not hardcode information gained from runs of previous teams. This is considered as cheating.
- A single robot is used.
- The robot must not leave the arena.
- Robots are allowed to carry three objects max. If more than 3 objects are above the robot's capacity, the same rule as for a major collision applies (run stopped or optional restart, stop after 2nd time).
- The robot has to start and end at the respective arena location (START, FINISH).
- Reaching each active Service Area successfully is rewarded once with points. Service Areas count as successfully as defined in section 3.7.
- Manipulation tasks count as successful as defined in section 5.2.
- Teams that manipulate ATTCs will earn manipulation points as described in 6.1, teams that manipulate real objects will earn a 20% bonus to their score.
- The score for each test will be calculated as defined in section 6.1.
- Teams that complete tasks in the region without landmarks with real objects can earn up to 20% bonus on their final score for both manipulation and location independently.
- After the confirmation and recording of the scores, no changes will be allowed.
- All tests will have a duration of 15 minutes, and each preparation phase will have 3 minutes. More than one round may be conducted for the same test, depending on the number of registered teams.

5.2 Definition of a Successful Manipulation

An object is considered successfully captured if the robot picks up the correct object from the correct service area and carries it out of the Manipulation Zone, which is treated with imaginary boundaries of infinite height.

If the object subsequently falls during transport, this does not invalidate the object's capture; however, it cannot be manipulated again and must be removed from the arena by the team leader.

A robot may lift other objects, as long as these objects are not completely removed from the Manipulation Zone. This allows a robot to pick up and inspect all objects at the workstation with its camera from multiple angles. Removing an incorrect object from the Manipulation Zone is treated as Incorrect Object Manipulation.

5.3 Basic Tests

5.3.1 Basic Manipulation Test

- On a table, there will be 4 ATTCs (two red and two blue) in a straight line in random order.
- The robot must organize the ATTCs by placing the blue ones in the blue container and the red ones in the red container.

5.3.2 Basic Transportation Test I

- Four ATTCs objects selected randomly must be transported, they will be marked by their IDs in April Tags.
- The task only can be performed with ATTCs without bonus
- There will be no active service areas just Stacking Area
- All four objects need to be stack at Stacking Area.

5.3.3 Basic Transportation Test II

- Five objects Figure[11] selected randomly must be transported.
- There will be four active service areas, depending on the local organization each covering one of the four table heights (5, 10, 15 cm).
- Physical obstacles are placed inside the arena (one fully blocking, one semi-blocking) on both sides making area bonus possible.

5.4 Advanced Tests

5.4.1 Advanced Manipulation Test

- On a table, there will be 7 April Tags (with IDs ranging from 1 to 7) arranged in a straight line in a random order.
- This task can be done with ATTCs or with real objects for a bonus of up to 20%.
- The robot must arrange the April Tags in a straight line in ascending numerical order.

5.4.2 Advanced Transportation Test I

- Six objects (Figure[12], Figure[13]) selected randomly must be transported for a bonus of up to 20%. ATTCs can be used to perform the task without bonus.
- Three randomly selected distraction objects are placed in one or more randomly selected active service areas.
- There will be six active service areas (three on marked side and three on the other side).

- All table heights available will be used.
- An object must be placed on a shelf (top part).
- Virtual walls (red/withe tape) are placed inside the arena.

5.4.3 Advanced Transportation Test II

- Eight randomly selected objects, including at least two from Figure[11], two from Figure[12] and two from Figure[13] and two ATTCs.
- If the team uses real objects for this task, the two ATTCs do not generate bonuses.
- There will be six active service areas (three on marked side and three on the other side) at least one shelve each side.
- All table heights available will be used.
- Two blue Objects with the lowest IDs must be placed in the blue container.
- Two red Objects with the lowest IDs must be placed in the red container.
- Two Objects with the highest IDs must be placed on the top shelf.
- The remaining two Objects must be positioned on the precision table.
- If the team uses real objects for this task, the two ATTCs must be placed on the precision table regardless of the value of their IDs.
- A virtual obstacle and a physical obstacle are placed inside the arena.

5.5 Finals

The Final acts as the complete design for the robots, including all elements of RoboCup@Work. With the number of active objects and service areas at an all-time high, the speed of planning and executing tasks could become a limiting factor for competing robots.

It is up to the organization to select the teams for the final. If few teams are participating in the competition, everyone will go to the final to value everyone's participation

Final

- Ten randomly selected objects have to be transported.
- All service areas will be active.
- All available table heights are used (0-15 cm).
- Two objects must be picked from a shelf (lower part).
- Two objects must be placed on a Stacking Area.
- Two objects must be placed on a shelf (top part).
- Two ATTCs objects must be placed in the Precision Placement table.

- If the team uses real objects for this task, the two ATTCs do not generate bonuses.
- Four objects must be placed into a container (two in blue, two in red).
- Two physical obstacles are placed inside the arena.
- Two virtual walls are placed.
- The task can be performed with the ATTCs without bonus.

6 Scoring and Ranking

6.1 Scoring

For each test, the final score is calculated individually for each team. This takes into account the bonuses available for navigation and object manipulation. Scores between tests may vary, but to avoid disadvantages, all teams must run through the same challenge arena. The result will then be calculated based on the points table.

Successfully concluded	Points
Arrived at the Service Area	100
Identified objects	100
Caught Objects	50
Objects Moved to the Correct Workspace	100

Tabela 1: Table of scoring.

A "Perfect Run" occurs when all tasks in a challenge are successfully completed within the given time. If this is achieved, an extra point will be awarded.

The score is given by multiplying the number of test objects by 30 points. Manipulating real objects guarantees a bonus at the end of the task.

Number of Objects	Scoring
1	30
2	60
3	90
4	120
5	150

Tabela 2: Example of scoring based on numbers of objects.

6.2 Bonus time

If a team finishes the work within the given time, the remaining time will be converted into an extra score, called Bonus Time. The remaining time is converted to seconds, and for each second it is multiplied by 1, resulting in the total extra score.

6.3 Simplifications

Teams may use simplifications, which will result in a reduction of scores for the given run. The simplifications may be chosen per run, but need to be announced to the referees before the start of the run. Each case will be analyzed individually.

6.4 Penalties

Penalty points are given as follows, each time again the incident occurs:

ATTENTION: Cheating results in team disqualification and all points already earned are forfeited.

Situation	Scoring
Drop Objects	-100
Incorrect Manipulation	-50
Minnor Colision	-50
Major Colision	Restart or -50%
Tape collision	-5% up to 25%
for each human interaction during the run	-100
Cheating	reset all points to 0

6.5 Collision

For reasons of safety of people and property it is strictly unwanted for the robot to collide with any of the environmental objects. Only collisions of the gripper with the upside of the service areas are allowed while a Grasping or Placing process. In all collision cases the (Virtual) Walls and Obstacles have an infinite height. The different types of collisions that can occur are defined in the following sections. Any collision causes a point penalty.

6.5.1 Major Collision

If the robot (platform and manipulator) collides with a static element of the environment or touches a Virtual Wall it is considered as a major collision. An exception of this rule is when the cables of the manipulator touches the environment while the Grasping or Placing process. As stated before a collision with the gripper with the upside of the service areas is allowed as long as there is no fundamental change of the environment at the service area. In this case it would be considered as a major collision. This could be for example moving an arbitrary surface off the workspace.

If a major collision occurs the first time, the team can decide between the following two options:

- stop the run and get 50% of the already reached points;
- restart the run (the normal restart rules apply).

The decision will likely depend on the remaining run time. If a second major collision occurs, the execution is stopped and the team receives 50% of the points achieved in the second attempt.

6.5.2 Minor Collision

If the Robot collides with (Manipulation) Objects, Decoys or Containers while moving through the arena it is a Minor Collision. Collisions with Objects, Decoys or Containers while grasping or placing process is considered as Manipulation Deduction.

6.5.3 Tape Collision

The red/white ribbon is called Barrier Tape and represents a Virtual Obstacle. If any part of the robot touches the barrier tape, it is considered a Tape Collision. Collisions with Tape induce a point penalty proportional to the final points of the execution. On the first collision there is a 5% penalty. On the second collision, the penalty increases to 10%. On the third collision, the penalty is 25%. Additionally, full collision may require restarting the test.

6.6 Restart

Teams might use one so-called restart in a run. Scores achieved before the restart are set to zero.

6.7 Other considerations

Any other issue not previously addressed in the rules or specific cases are dealt with in this section.

6.7.1 Lighting Conditions

The local committee will try to provide uniform lighting throughout the arena. However, teams should be prepared to calibrate their robots based on the lighting conditions of the venue. The local committee will take actions to minimize the effects of shadows and natural light, however these factors cannot be completely eliminated. Therefore, it is highly recommended that competitors design their robots to be immune to the variations of lighting that can be presented in the venue during the competition. From the start of competitions, the teams will "play" under existing lighting conditions without discussion or claims.

6.7.2 The Jury

The JURY is composed by a member of organizing chairs, an auxiliary of the organization and a member of another team that is not competing in the match, chosen before the match starts. The JURY is responsible for the execution of the round.

6.7.3 Extraordinary Situations During the Competition

If there is any situation not covered under the above-mentioned rules, or any doubt about the score, it will be up to the judges and the organizers of the competition to consider the case in the greatest possible impartiality and decide. It is important to mention that any fact that it is not explicit in the rules cannot be automatically considered as allowable in the competition. Missing facts will always be treated as **extraordinary situation**, and it must be judged as allowable or not by the judges and organization.

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