

WORLD ROBOT SUMMIT 2020

PARTNER ROBOT CHALLENGE

Real Space

Rules & Regulations



May 15, 2019

About this Rulebook

This is the official rulebook of the Partner Robot Challenge (Real Space) 2020 competition. It has been written by the Service Category Technical Committee members.

Acknowledgements

We would like to thank all the people who contributed to the World Robot Summit Service Category Technical Committee members with their feedback and comments. We also like to thank the members of RoboCup@Home community.

Contents

1	Introduction	3
1.1	Service Robotics Category	3
1.2	Partner Robot Challenge	3
2	Partner Robot Challenge	
	Real Space	4
2.1	Concept	4
2.2	Competition	4
2.3	Standard Robot Platform	5
3	General Rules	
	Tidy Up Here	6
3.1	Objectives	6
3.2	Technical Focus	6
3.3	Vision	6
3.4	Settings	6
3.5	Before the Competition	10
3.6	During the Competition	10
3.7	Scores	11
3.8	Additional rules and remarks	14
3.9	Data Recordings	15
3.10	Score Sheet	16
4	Appendix	18
4.1	Furniture models	18
4.2	Arena Setup	22
4.2.1	Room 1	22
4.2.2	Room 2	25

1 Introduction

1.1 Service Robotics Category

The Competition will be helpful to solve social problems stemming from rapidly aging population and declining birth rates through technology that works alongside humans to provide a variety of services. As we enter the age in which robots will become a part of people's lives, there is a need for robots that can perform a variety of services in cooperation with humans. There is a need for service robots that can work safely and reliably with people and for technologies that create the environment necessary for developing such robots. These include AI learning through which humans and robots engage in advanced communication, Big Data information-sharing through clouds, collection and use of information gathered through IoT technology, etc. Human resource development (training) is indispensable in the development of robotic technology and social implementation of robots.

1.2 Partner Robot Challenge

The concept of Partner Robot Challenge is to foster the collaboration between human and robot. Not limited to assistance for handicapped person, but also in domestic home environment with living children and elderly person, it is targeted to realize a rich collaborative living environment for human and robot. It is not the aim of this competition for the robot to complete the task alone, but with the communication and workload sharing with human user, this challenge competes the technologies for smooth collaboration between human and robot. The focus on human-robot collaboration is the uniqueness of this competition.

2 Partner Robot Challenge Real Space

2.1 Concept

The concept behind the competition is adapted from the roles of a home assistant. A home assistant is trained to aid or assist human on daily house chores. Apart from physical work assistance, the home assistant can also maintain friendship and social companionship with human. The fundamental concept of this challenge is to develop a robot that resembles a home assistant as a partner to support human.

In the competition, the robot is to compete for the task as a home assistant. Not limited to the support for handicapped person, the robot is anticipated to be able to perform a wide range of tasks as a partner to elderly person and normal healthy person too.



Figure 1: Concept of the Partner Robot Challenge.

2.2 Competition

The competition consists of a qualifier round, semi-final, and a final.

The objective is to evaluate the fundamental skills of the robot to accomplish basic functions of a home assistant, such as serving items, searching items, and tidy-up the environment. The robot (with human collaboration) is required to perform such tasks within a set of defined rules and environments in order to acquire scores for the competition. The competition ends with the Final where only the two highest ranked teams compete to become the winner.

The teams are encouraged to demonstrate their latest research development on new approaches, applications of the assistance robot in an interesting scenario

2.3 *Standard Robot Platform*

setting. A primary objective of the competition is to assess all the different solutions from the many teams to the very same problem.

2.3 Standard Robot Platform

The Human Support Robot¹(HSR) by Toyota Motor Corporation will be used as the Standard Platform Robot for the Partner Robot Challenge (Real Space).

¹Takashi Yamamoto et. al. *Development of Human Support Robot as the research platform of a domestic mobile manipulator*. ROBOMECH Journal, 2019.

3 General Rules

Tidy Up Here

Description: Move the objects spread around a room to their designated locations and providing a person with something to drink when requested.

Time: 15 min for task 1 + 5 min for task 2

3.1 Objectives

- Task 1: Tidy up objects from the incorrect positions to a predetermined tidy up space.
- Task 2: Provide a person within a group with a drink from a shelf when requested while avoiding obstacles when navigating.

3.2 Technical Focus

- Semantic mapping, unknown object perception and manipulation, path planning.
- HRI, semantic mapping, object manipulation, motion and path planning.

3.3 Vison

By providing an easy to understand challenge, we aim at identifying and solving front-end problems that might arise when using a service robot in indoors environments, such as safety and stability, autonomous error recovery, task performance and time consumption, natural motion and path planing, etc.

The Key Performance Indicator is based on a 4S philosophy: Speed, Smooth/Smart, Stable, and Safe.

3.4 Settings

Environment

- The furniture positions will be announced in advance (including the room layout, furniture arrangement, furniture models, etc., as in Figure 2).
- Each Task is carried out in the following rooms:
 - Room 1: Living room (Task 1), a 3.5x4.0 meters area, with a 1.2m long free access (i.e. without door) in one on the long sides (left wall, top side) connecting to the dining room, and a 1.2m long door in a short side working as a main entrance (bottom wall, right side), as shown in Figure 3a.
 - Room 2: Dining room (Task 2), a 2.5x4.0 meters area, as illustrated in Figure 3b.

3.4 Settings

- The operator sends instructions from the living room, including what object to deliver in Task 2.
- Furniture:
 - Task 1: stairs-like drawer (Figure 4a), long table (x2), tall table, bin (x2).
 - Task 2: shelf with door (Figure 5), chair (x2).
- Storage places:
 - Task 1: drawer, tray, bin, pen pencil holder (Figure 6).
 - Task 2: shelf with door.

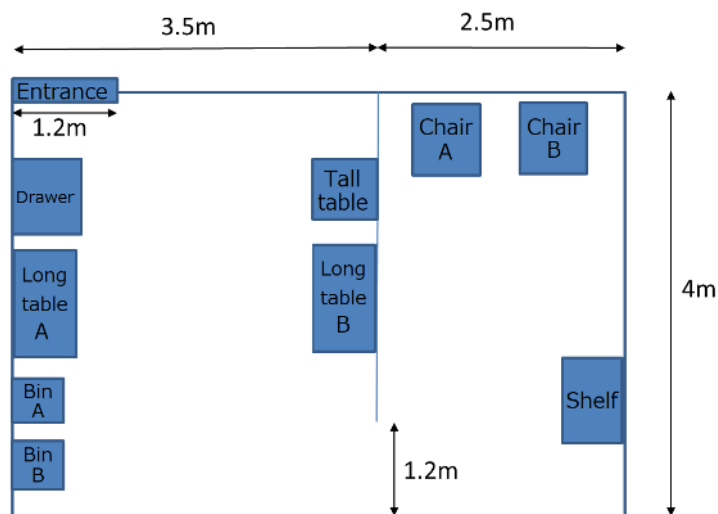


Figure 2: Test arena layout.

Objects

- Known objects - with pre-announced object recognition data and location information –, 25 units in 5 categories² (each category has 5 units randomly chosen from the dataset; the selection process is performed per test):
 - Food (e.g. chips can, coffee can, cracker box), kitchen items (e.g. glass, bowl, mug), tools (e.g. scissors, markers, screwdrivers), shape items (e.g. baseball, tennis ball, foam brick), and task items (e.g. Rubick's cube, t-shirt, airplane toy)
- Unknown objects - without pre-announced object recognition data nor location information. They will be frequently used daily goods and tools

3.4 Settings



Figure 3: a) Living room where objects are scattered about. b) Dining room with a shelf and a two chairs. For ease of visibility for the audience, **the wall will be 60 cm height and 10 cm width.**



Figure 4: a) Stairs-like drawer. The drawer will be as it is (left drawer) or it might have a handle and/or be opened under team request (middle drawers). b) Several views of the easy-to-manipulate handles in two different sizes, namely large (top part of the image) and short (bottom part).

as in Young Sang Choi et. al. ³, and may include deformable objects such as clothing, food, magazines, etc., 5 units (one per category).

Object's specifications and their corresponding 3D models can be found in <http://www.ycbbenchmarks.com/>.

Tidy Up

- The name and location of the tidy up spaces are fixed, such as bakery drawer, tableware tray, textile bin, pen pencil holder, etc.

²Berk Calli et. al. *Benchmarking in Manipulation Research: The YCB Object and Model Set and Benchmarking Protocols*. IEEE Robotics and Automation Magazine, 2015.

³Young Sang Choi et. al. (2009), *A list of household objects for robotic retrieval prioritized by people with ALS*. IEEE International Conference on Rehabilitation Robotics, ICORR 2009.



Figure 5: a) Front view of the shelf and objects in it. b) Door with an easy-to-manipulate handle.



Figure 6: Containers may vary in shape and size, but they will be within a predefined area in the delivery zone.

- Known objects are given with pre-announced information on tidy up

3.5 Before the Competition

spaces (toys are in task items bin, vegetables are in food drawer, and so on).

- For unknown objects, the robot inquires the operator to get information on tidy up space (by voice or QR code), or by the robot own judgement (e.g. toys go into task items bin or food drawer?).
- The furniture doors will have easy-to-manipulate handles (as in Figure 4b).

3.5 Before the Competition

- Teams are given the time to create/adjust map data in the actual apartment (no objects are placed), and to memorize unknown objects.
- Each team will be given setup time in turns during the setup day.
- Right before the competition, the referee sets the rooms into messy condition (within a specified error tolerance range).
- Area 1. Living room (task planning, object recognition and manipulation): for Task 1
 - 30 objects (5 categories, 5 known + 1 unknown objects per category) are randomly placed in the room (on the floor and or tables).
- Area 2. Dining space (HRI, path planning): for Task 2
 - Obstacles on the floor are set in the access between rooms. Several objects (food and drinks) are placed inside the shelf. Some people are in the dining room.

3.6 During the Competition

The robot enters the living room in a messy condition, tidy up the room in 15 minutes, then moves to the dining room while avoiding obstacles on the floor and delivers the drink in 5 minutes.

Several teams are expected to participate and two identical arenas are set up. From all teams, two groups are generated and a group-tournament is considered, with quarter-finals, semi-finals and a final. Each team competes against all others in their bracket, where two teams perform the same task in parallel (Arena A and Arena B). A match winner gets 3 points, a draw gives 1 point to each team, and a defeat makes 0 points. After the qualifiers, the top-ranked teams progress to the next round. A detailed description of a full match is described below:

- Each test starts with the operator's command in the Living Room at a predetermined point (starting point); the command includes the object to be delivered in Task 2.

- If the robot is stuck during the competition, it can be restarted as many times as needed. After the robot has been stopped by the operator, the robot should be restarted within 1 minute with a penalisation of -100 points and additional -100 per extra minute (to prevent repeatedly fine adjustments).
- When Task 1 has been completed or time limit is up, the robot moves to Room 2 to perform Task 2. The robot informs the operator whether the tasks have been completed or the time limit is up.
- Task 1
 - After indicating the object to be delivered in Task 2, start the competition with “Tidy up the living room” given by the operator.
 - Perform tidy up.
 - Moves to Room 2 after completion of the task or the time is over (15 min \pm 15 sec).
- Task 2a
 - Enters the dining room while avoiding obstacles.
- Task 2b
 - The robot goes directly to the shelf, opens it, and takes the right object given at the beginning of the test.
 - The robot moves toward the group of persons and gives the drink to the one requesting it.
 - The test ends with the robot reporting the completion of the task or the time is over (5 min \pm 15 sec).

3.7 Scores

- Task 1
 - Grasping an object inside the room (it is considered a successful grasping if the robot is able to bring the object to a deposit area; if the robot drops the object in its way to a deposit, it is considered unsuccessful. Hint: the robot can take a dropped object again): 10 points x 30 units.
 - Correctly depositing an object in a location (a successful deposit consist on the object being inside the deposit, as in Figure 7). Special consideration is given to clothing and textiles, where they can hang in the deposit's border, but without touching the floor (Figure 8)): 10 points x 30 units.

3.7 Scores

- Correctly depositing an object according to its category: 10 additional points per object.
- Correctly depositing an object based on its orientation (e.g. cups facing upwards or pencil tips facing downwards as in Figure 9): 10 additional point per object.
- Finishing the task within the time limit: 50 points.
- Task 2a
 - Navigating to the next room while avoiding random obstacles lying on the floor within the access area: 100 points.
- Task 2b
 - Taking the drink among many objects in the shelf. Note that the requested object is likely to be occluded by other items in the shelf and therefore a grasping strategy should be implemented (e.g. first move item one and item two in front of the target object before being able to take it): 100 points x 1 unit.
 - Correctly detecting a person request and giving the drink to her/him: 100 points x 1 person.
 - Finishing the task within time limit: 50 points.
 - If any time remaining, add 20 points per minute.
- Total: Maximum points per match without considering bonuses or penalties: 1000.
- The final score in a full round is the sum of partial scores per match in their corresponding bracket.

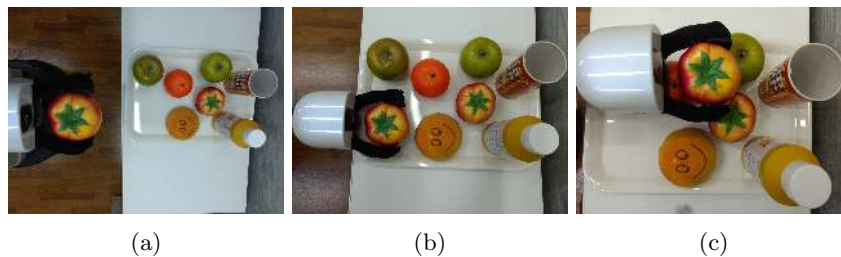


Figure 7: Example of a delivery process: a) given a target deposit with objects in it, b) it is considered a correct delivery if the objects is placed softly in a free space, and c) wrong if it is places in a occupied space.

3.7 Scores



Figure 8: a) Correct cloth delivery (no contact with the floor) and b) an incorrect delivery.

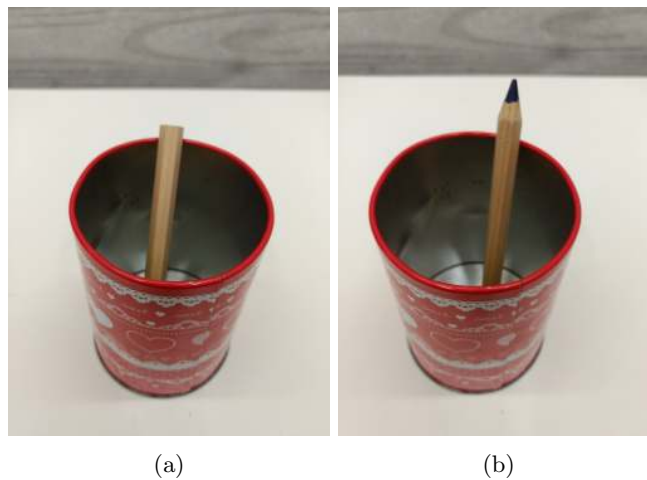


Figure 9: Example of a a) correct and b) incorrect orientation-based delivery, where the pencil's tip should face downwards.

- Bonus points can be given if the team opts for the bonus challenges (50 points per challenge):
 - Hard-to-grasp object manipulation, this includes objects in difficult places, like at the end of or under the table, textureless and or flat objects (see Figure 10).
 - Opening the house door.
 - Opening the drawers.
 - Opening the three shelf doors.

3.8 Additional rules and remarks

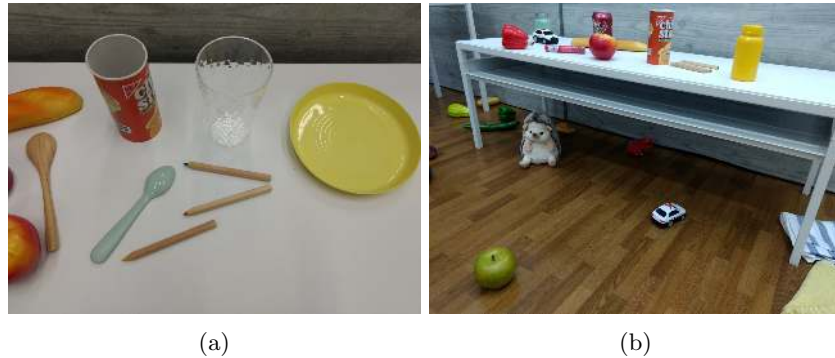


Figure 10: Hard-to-manipulate objects include a) flat, textureless, and transparent objects, and b) objects in difficult places such as under tables.

- Penalty points can be given in the following scenarios:
 - The robot moves to room 2 before the task is completed or the time limit (± 15 seconds) is reached: -100 points.
 - The robot (except the manipulator) or the additional equipment prepared by the team hits the furniture or the objects/obstacles inside the arena: -50 points per hit.
 - Dropping an object (however, if the robot successfully re-takes the same object, no penalisation will be considered): -10 points per object
 - The robot performs a false delivery (i.e. moves to the deposit location without holding any object in its manipulator): -10 points per delivery.

3.8 Additional rules and remarks

- The use of an external laptop mounted in the back of the robot is allowed.
- The robot can use any type of external computing (e.g. cloud computing) and can connect to it via wireless (WiFi provided, but not guaranteed).
- Hand manipulator can be changed (i.e. only the gripper design), TOYOTA will provide the drawings and manuals under request. Safety and motion tests should be confirmed by each team prior and during the competition.
- The use of external tools (carts, trays, etc.) is allowed (no actuators or active devices) to deliver multiple objects at the same time.
- Passive sensors (e.g. depth sensors mounted in the hand, such as lasers or sonars) are allowed within the restrictions to be provided by TOYOTA. However, no actuators are allowed (active devices).

3.9 *Data Recordings*

- Random robot inspections will be performed during the competition.

IMPORTANT: Before using external tools or performing any hardware modification, teams should submit to the committee a letter of intent specifying the details of such tool or modification to receive approval and or feedback.

3.9 Data Recordings

The following data may be required by the referee to support scoring.

- Recognised object images.
- List of manipulated objects.

3.10 Score Sheet

Total score per match:

Performance	Score	Points
Task 1		
Grasping an object inside the room	10 x 30	
Correctly depositing an object in a location	10 x 30	
Correctly depositing an object in a location according to its category	+10 per object	
Correctly depositing an object based on its orientation (e.g. cups facing upwards, pencil tips facing downwards)	+10 per object	
Finishing the task within the time limit (15 min \pm 15 sec)	50 points	
Task 2a		
Successfully entering the arena without collisions	100	
Hitting an obstacle	-50 per hit	
Task 2b		
Taking the target object among many objects in the shelf	100	
Taking the wrong object	-70	
Correctly detecting a person request and giving the drink to her/him	100	
Delivering the object to the wrong person	-70	
Finishing the task within time limit (5 min \pm 15 sec)	50	
Special Bonuses		
If any time remaining, add 1 points per minute	20 x time	
Bonus challenges (Hard-to-grasp object manipulation, Opening the house door, Opening the three drawers, Opening the shelf door)	50 per challenge	
Penalties		
Moving to the next room before time	-100	
Hitting the furniture or the objects/obstacles inside the arena	-50 per hit	
Dropping an object without re-taking it	-10 per object	
Performing a false delivery	-10 per delivery	
Restart (within one minute)	-100	
Additional restarting time	-100 per minute	
Total (no penalties/bonuses considered)		1000

3.10 Score Sheet



Total points per match (win: 3, draw: 1, defeat: 0):

Match	Team							
	Group A				Goup B			
	I	II	III	IV	V	VI	VII	VII
1								
2								
3								
Total								
	S1		S2		S3		S4	
1								
	F1				F2			
1								

4 Appendix

4.1 Furniture models

Note: units are in meters in the following order: width x length x height.

- stairs-like drawer (white structure, orange drawers):
Link: <https://www.ikea.com/us/en/catalog/products/S89857541/#/S59128935>
- long table (white):
Link: <https://www.ikea.com/us/en/catalog/products/00342640/>
- tall table (white):
Link: <https://www.ikea.com/us/en/catalog/products/20342644/#/60342642>
- bin (two bins, one green and the other black):
Link: <https://www.ikea.com/us/en/catalog/products/10300319/>
- shelf (white):
Link: <https://www.ikea.com/us/en/catalog/products/00263850/>
- chair (white structure, gray cover):
Link: <https://www.ikea.com/us/en/catalog/products/S69100163/>

Name	IKEA's Model	width	length	height	Image
stairs-like drawer	591.289.35	0.44m	0.99m	0.94m	Figure 11
long table	003.426.40	0.40m	1.20m	0.40m	Figure 12
tall table	603.426.42	0.40m	0.40m	0.60m	Figure 13
bin	103.003.19	0.38m	0.33m	0.33m	Figure 14
shelf	002.638.50	0.28m	0.80m	2.02m	Figure 15
chair	691.001.63	0.58m	0.54m	0.97m	Figure 16

Table 1: Furniture's model and size to be used during the tests and competition.

4.1 Furniture models

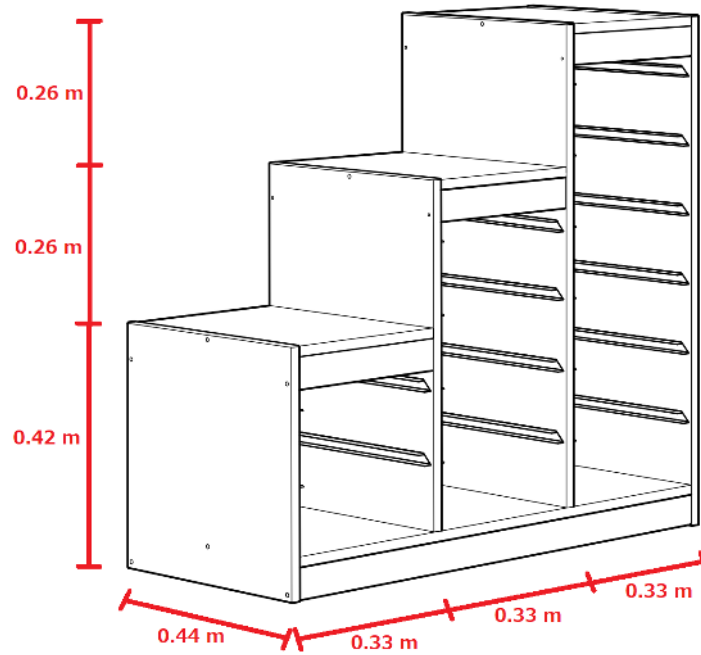


Figure 11: Stairs-like drawer model (width 0.44 m, length 0.99 m, height 0.94 m).

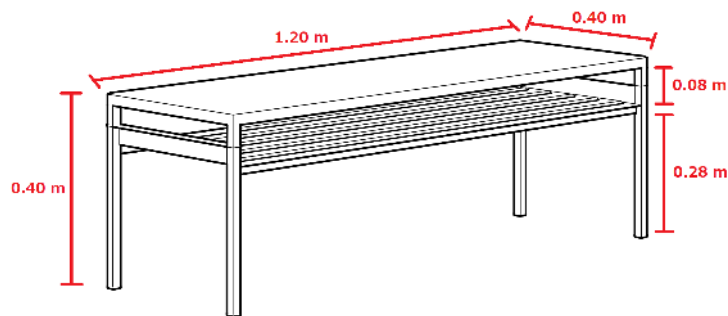


Figure 12: Long table model (width 0.40, length 1.20, height 0.40 m).

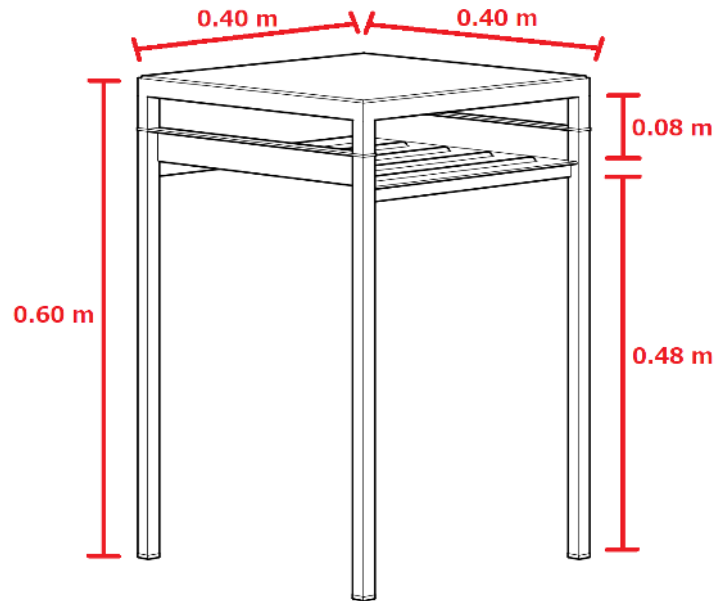


Figure 13: Tall table model (width 0.40, length 0.40, height 0.60).

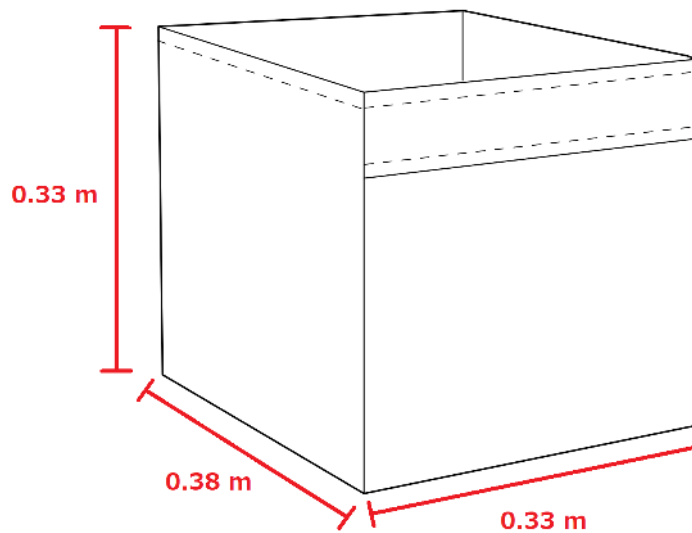


Figure 14: Bin model (width 0.38, length 0.33, height 0.33).

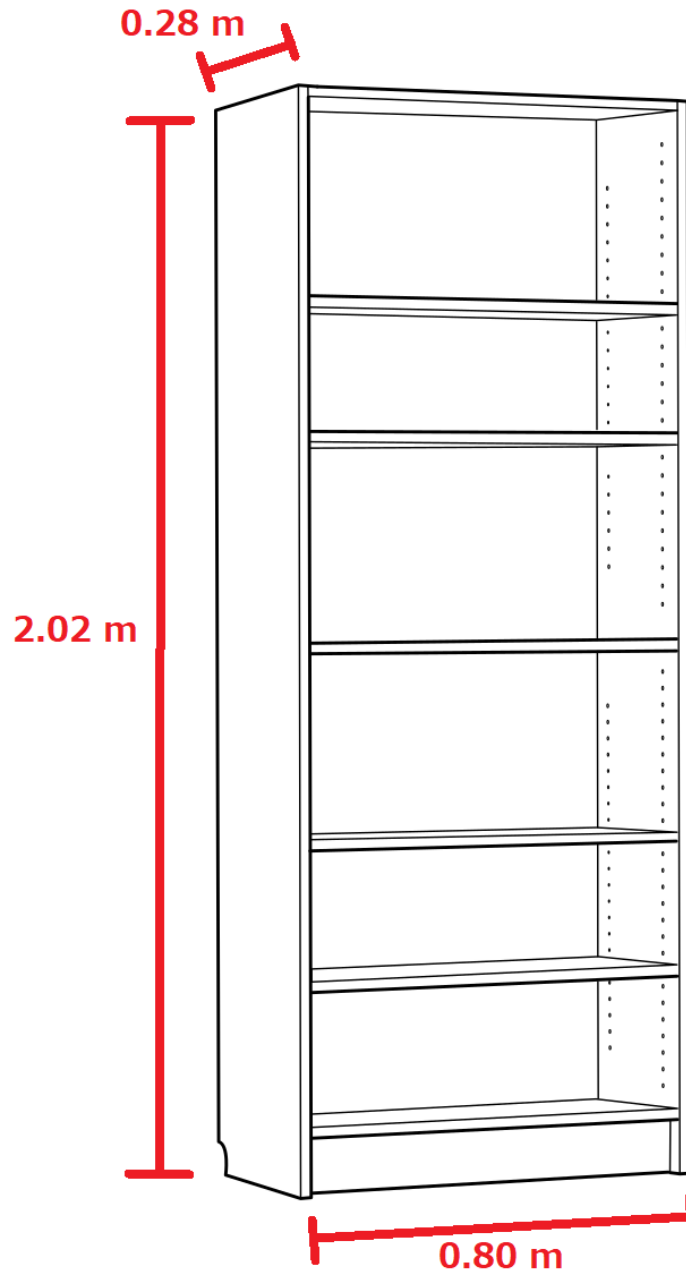


Figure 15: Shelf model (width 0.28, length 0.80, height 2.02).

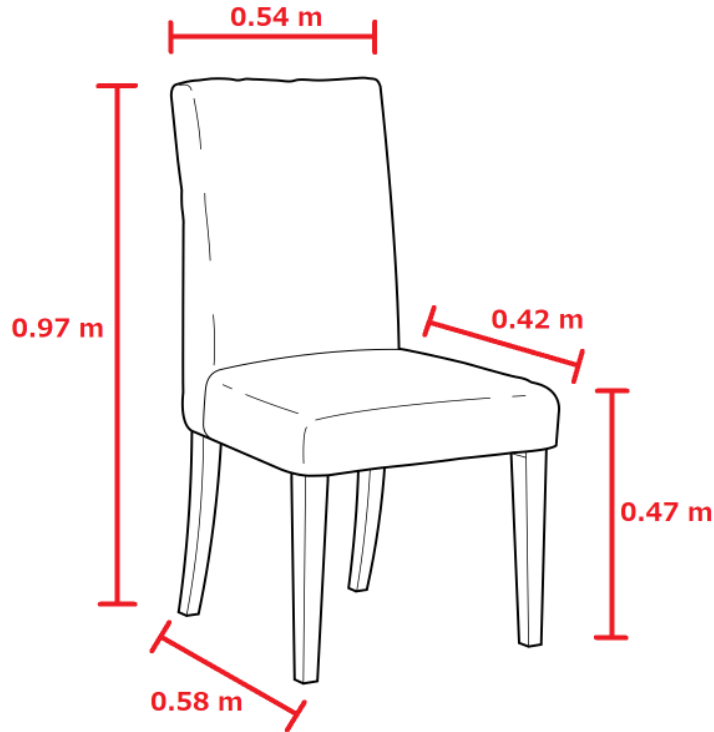


Figure 16: Chair model (width 0.58, length 0.54, height 0.97).

4.2 Arena Setup

The arena setup consists of two rooms (Room_1 and Room_2), one per task, as in Figure 17.

4.2.1 Room 1

In Task_1, the room is divided in two main areas, the **Search Area**, where the objects are scattered around, and the **Deposit Area**, where the objects should be placed.

The furniture regarding the Deposit Area includes the Drawer, Long Table, Bin_A, and Bin_B. In detail, the Drawer is divided in Drawer_left, Drawer_top, and Drawer_bottom (see Figure 18).

Furthermore, the Long Table includes two types of deposits: tray and container. There are two similar trays (Tray_A and Tray_B) and two containers (Container_A and Container_B). The Container_A should be small enough to contain pens/pencils/markers vertically in order to be able to evaluate the correct orientation.

A summary of the deposits per category can be found in Table 2. As a

4.2 Arena Setup

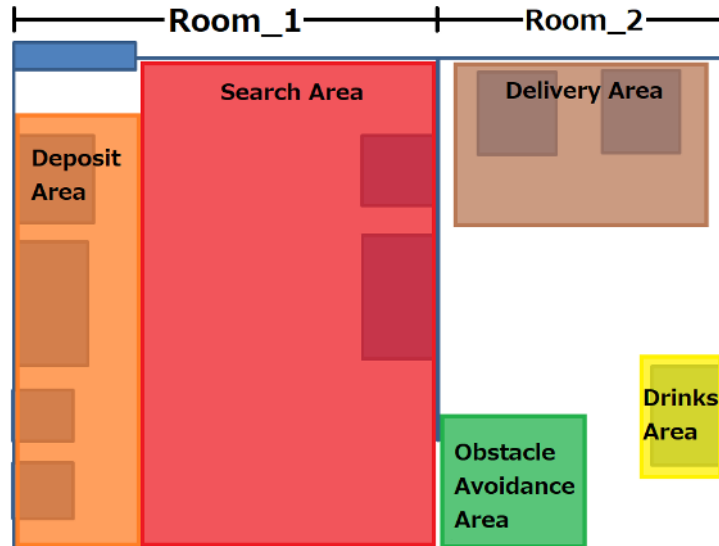


Figure 17: Test arena by interaction areas. There are two rooms, one per task, and five main areas: Deposit, Search, Obstacle Avoidance, Drinks, and Delivery areas.



Figure 18: In the stairs-like drawer, only three drawers are going to be used, namely the Drawer_left, and middle Drawer_top and Drawer_bottom.

remainder, the object categories are as follows: Food (e.g. chips can, coffee can,

4.2 Arena Setup

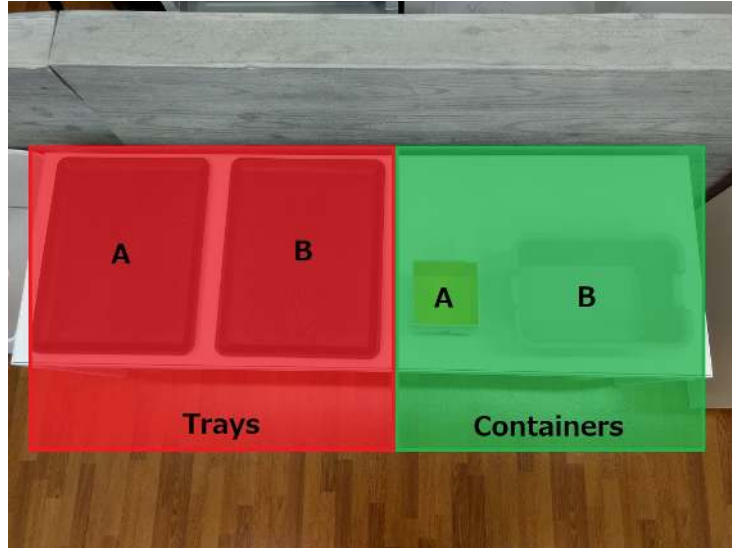


Figure 19: In the Deposit Area, on the Long Table A there will be four deposits: Tray A, Tray B, Container A, and Container B. As a reference, the tray's size is 0.38 x 0.36 m, Container A is 0.10 x 0.10 x 0.10 m, and Container B is 0.18 x 0.26 m and 0.11 m height. Single color deposits are considered to detect any tag or mark that might be used as a reference.

cracker box), kitchen items (e.g. glass, bowl, mug), tools (e.g. scissors, markers, screwdrivers), shape items (e.g. baseball, tennis ball, foam brick), task items (e.g. Rubick's cube, t-shirt, airplane toy), and unknown objects.

Deposit	Place	Category
Drawer_left	Drawer	Shape items
Drawer_top	Drawer	Food
Drawer_bottom	Drawer	Food
Tray_A	Long_Table_A	Tools
Tray_B	Long_Table_A	Tools
Container_A	Long_Table_A	Kitchen items
Container_B	Long_Table_A	Kitchen items
Bin_A	Bin_A	Task items
Bin_B	Bin_B	Unknown objects

Table 2: Object categories and their corresponding deposits in the arena, as in Figure 2.

4.2 Arena Setup

4.2.2 Room 2

Regarding Task 2a, the obstacles will be scattered around the access between rooms (i.e. the Obstacle Avoidance Area in Figure 17), and they consist in flat and small objects below the laser height (as shown in Figure 20), therefore, other detection strategies should be implemented to be able to avoid them.



Figure 20: Obstacles laying on the rooms' access. They consist in small and or flat objects.

In Task 2b, the drinks and other objects in the Drink Area will be placed inside a shelf (Figure 5 and Figure 15) with board levels at 0.50 m, 0.80 m, and 1.05 m height and three different depths: front, middle, and back, as shown in Figure 21. The target object may be at any depth and therefore a grasping strategy should be developed to softly move the objects obstructing the requested drink as necessary (e.g. if the drink is in the middle level and middle depth, first move any object in the front depth to a different level before being able to grasp the requested drink).

Finally, there will be two persons in the Delivery Area (they might be either standing up or sitting down) and one of them will be requesting a drink by waving her/his arm (it can be both the left or right arm).

4.2 Arena Setup



(a)

(b)

Figure 21: a) Top and b) front views of the objects' distribution at three different depths (front, middle and back).