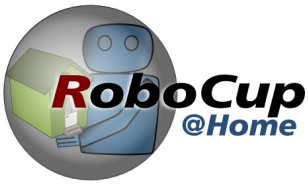

RoboCup@Home

Rules & Regulations

Version: 2017 Rev-660
Last Build Date: July 23, 2017 Time: 1110
Last Revision Date: 2017-06-11

About this rulebook

This is the official rulebook of the RoboCup@Home competition 2017. It has been written by the 2017 RoboCup@Home Technical Committee (in alphabetical order): Loy van Beek, Kai Chen, Kathrin Evers, Dirk Holz, Mauricio Matamoros, Hideaki Nagano, Caleb Rascon, Rodrigo Ventura, and Sven Wachsmuth.

How to cite this rulebook

If you refer to RoboCup@Home and this rulebook in particular, please cite:

Loy van Beek, Dirk Holz, Mauricio Matamoros, Caleb Rascon, and Sven Wachsmuth. "Robocup@Home 2017: Rule and regulations," http://www.robocupathome.org/rules/2017_rulebook.pdf, 2017.

```
@misc{rulebook_2017,
  author =       {Loy van Beek AND Dirk Holz AND Mauricio Matamoros
                  AND Caleb Rascon AND and Sven Wachsmuth},
  title =        {RoboCup@Home 2017: Rules and Regulations},
  year =         2017,
  howpublished = {\url{http://www.robocupathome.org/rules/2017_rulebook.pdf}},
}
```

Acknowledgments

We would like to thank the members of the technical committee who put up the rules and the organizing committee who organizes the competition.

People that have been working on this rulebook as member of one of the league's committees (in alphabetical order):

Loy van Beek	Luca Iocchi	Komei Sugiura
Kai Chen	Mauricio Matamoros	Rodrigo Ventura
Kathrin Evers	Alexander Moriarty	Sven Wachsmuth
Dirk Holz	Caleb Rascon	Tijn van der Zant

We also like to thank all the people who contributed to the RoboCup@Home league with their feedback and comments.

People that have been working on this rulebook as member the league (in alphabetical order):

Yuki Furuta	María T. Lazaro	Arturo Rodríguez García
Noe Hernandez Sanchez	@fibonatic	Maxime St-Pierre
Johannes Kummert	Florian Lier	Ramon Wijnands

Contents

Chapter 1

Introduction

1.1. RoboCup

RoboCup is an international joint project to promote AI, robotics, and related fields. It is an attempt to foster AI and intelligent robotics research by providing standard problems where a wide range of technologies can be integrated and examined. More information can be found at http://www.robocup.org/.

1.2. RoboCup@Home

The *RoboCup@Home* league aims to develop service and assistive robot technology with high relevance for future personal domestic applications. It is the largest international annual competition for autonomous service robots and is part of the RoboCup initiative. A set of benchmark tests is used to evaluate the robots abilities and performance in a realistic non-standardized home environment setting. Focus lies on the following domains but is not limited to: Human-Robot-Interaction and Cooperation, Navigation and Mapping in dynamic environments, Computer Vision and Object Recognition under natural light conditions, Object Manipulation, Adaptive Behaviors, Behavior Integration, Ambient Intelligence, Standardization and System Integration. It is collocated with the RoboCup symposium.

1.3. Organization

1.3.1. Executive Committee — ec@robocupathome.org

The *Executive Committee* (EC) consists of members of the board of trustees, and representatives of each activity area. Members representing the @Home league:

- Kai Chen (University of Science and Technology of China, China)
- Dirk Holz (University of Bonn, Germany)
- Caleb Rascon (Universidad Nacional Autonoma de Mexico, Mexico)
- Sven Wachsmuth (Bielefeld University, Germany)

1.3.2. Technical Committee — tc@robocupathome.org

The *Technical Committee* (TC) is responsible for the rules of each league. Members of the RoboCup@Home Technical Committee for 2017:

- Loy Van Beek (Eindhoven University of Technology, The Netherlands)

- Kathrin Evers (Technische Universität Dresden, Germany)
- Hideaki Nagano (Tokyo City University, Japan)
- Rodrigo Ventura (Institute for Systems and Robotics, Instituto Superior Técnico, Portugal)

The Technical Committee also includes the members of the Executive Committee.

1.3.3. Organizing Committee — oc@robocupathome.org

The *Organizing Committee* (OC) is responsible for the organization of the competition. Members of the RoboCup@Home Organizing Committee for 2017:

- Mauricio Matamoros (Universidad Nacional Autonoma de Mexico, Mexico)
- Francisco Javier Rodriguez Lera (University of Luxembourg, Luxembourg)
- Raphael Memmesheimer (University of Koblenz, Germany)
- Alexander William Moriarty (TBA, Bonn-Rhein-Sieg University; Germany)
- Jeffrey Too Chuan Tan (The University of Tokyo, Japan)

1.4. Infrastructure

1.4.1. RoboCup@Home Mailinglist

The official *RoboCup@Home mailing list* can be reached at

`robocup-athome@lists.robocup.org`

You can register to the email list at:

http://lists.robocup.org/cgi-bin/mailman/listinfo/robocup-athome

1.4.2. RoboCup@Home Web Page

The official *RoboCup@Home website* that also hosts this RuleBook can be found at

http://www.robocupathome.org/

1.5. Leagues

RoboCup@Home is divided in three Leagues. Two of them are *Standard Platform League*s for which all competitors use the same robot, and one that grants complete freedom to all competitors. The official leagues and their names are:

- the *RoboCup@Home Domestic Standard Platform League*,
- the *RoboCup@HomeSocial Standard Platform League*, and
- the *RoboCup@Home Open Platform League*

Each league points out to a different aspect of service robotics, reason for which they target specific abilities.

Figure 1.1.: Toyota HSR

1.5.1. Domestic Standard Platform League

The *Domestic Standard Platform League*(DSPL) has as main goal to assist humans in a domestic environment, paying special attention to elderly people and people suffering of illness or disability. In consequence, the DSPL focuses on Ambient Intelligence, Computer Vision, Object Manipulation, Safe Indoor Navigation and Mapping, and Task Planning.

The robot to be used in the DSPL is the Toyota HSR, shown in Figure 1.1.

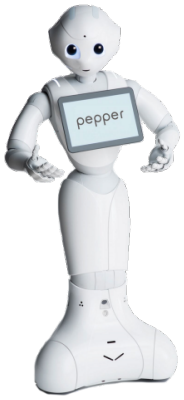

Figure 1.2.: Softbank / Aldebaran Pepper

1.5.2. Social Standard Platform League

With a 180 degree turn in Human Robot Interaction, the *Social Standard Platform League*(SSPL) takes robots away from the traditional passive servant role, for now the robot is the one who will actively look for interaction. From a party waiter in a home environment to a hostess in a museum or shopping mall, in *SSPL* look for the next user who may require its services. Hence, this league focuses on Human-Robot Interaction, Natural Language Processing, People Detection and Recognition, Reactive Behaviors, and Safe Outdoor Navigation and Mapping.

The robot to be used in the SSPL is the Softbank/Aldebaran Pepper, shown in Figure 1.2.

1.5.3. Open Platform League

The *Open Platform League*(OPL) has the same modus operandi used since the fundation of RoboCup@Home till 2017 when Standard Platform Leagues were created. With no hardware constrains, OPL is the league for teams who want to test their own robot designs and configuration, as well as for old at-homers. In this league robots are tested to their limits without having in mind design restriction, although the scope is similar to the DSPL.

1.6. Competition

The competition consists of 2 *Stages* and the *Finals*. Each stage consists of a series of *Tests* that are being held in a daily life environment. The best teams from *Stage I* advance to *Stage II* which consists of more difficult tests. The competition ends with the *Finals* where only the two highest ranked teams of each league compete to select the winner.

1.7. Awards

All the awards need to be approved by the RoboCup Federation (RCF). Based on RCF's decisions, some of them may not be given.

The RoboCup@Home league features the following *awards*.

1.7.1. Winner of the competition

For each league, there will be a 1st, 2nd, and 3rd place award trophies (first and second place only when the number of teams is eight or less).

1.7.2. Best Human-Robot Interface award

To honour outstanding Human-Robot Interfaces developed for interacting with robots in the @Home league, a special *Best HR Interface award* may be given to one of the participating teams. Special attention is being paid to making the interface open and available to the @Home community.

The *Executive Committee* (EC) members from the RoboCup@Home league nominate a set of candidates for the award. The *Technical Committee* (TC) elects the winner. A TC member whose team is among the nominees is not allowed to vote.

There is no Best HR Interface award in case no outstanding interface and no nominees, respectively.

1.7.3. Best Poster

To foster scientific knowledge exchange and reward the teams' effort to present their contributions, as of 2017 all scientific posters of each League will be evaluated, having the chance of receiving the award for the *Best RoboCup @Home DSPL Poster*, the *Best RoboCup @Home OPL Poster*, or the *Best RoboCup @Home SSPL Poster*, respectively.

Candidate posters must present innovative and State-of-the-Art research within a field with direct application in RoboCup @Home in an appealing, easy-to-read way; demonstrating successful and clear results. In addition to be attractive and well-rated in the Poster Session (see Section 4.3), the explained research must have impact in the team's performance during the competition.

The *Executive Committee* (EC) members from the RoboCup@Home league nominate a set of candidates for the award. The *Technical Committee* (TC) elects the winner. A TC member whose team is among the nominees is not allowed to vote.

1.7.4. Skill Certificates

The @Home league features certificates for the robots best at a the skills below:

- Navigation
- Manipulation
- Speech Recognition
- Person Recognition

A team is given the certificate if it scored at least 75% of the attainable points for that skill. This is counted over all tests and challenges, so e.g. if the robot scores manipulation points during the Help-me-Carry test to open the door, that will count for the Manipulation-certificate. The certificate will only be handed out if the team is *not* the overall winner of the competition.

1.7.5. Open-source software award

Traditionally –since Nagoya 2017– RoboCup@Home awards the best contribution to the community by means of open source software solutions. The software must be easy to read, properly documented, follow standard design patterns, be actively maintained, and meet IEEE software engineering metrics of scalability, portability, maintainability, fault tolerance, and robustness. In addition, the open sourced software must be made available as a framework-independent standalone library so it can be reused with any software architecture.

Candidates must send their application to the *Technical Committee* (TC) at least one month before the competition by means of a short paper (max 4 pages) following the same format used for the *team description paper* (see Section 3.1.4), including a brief explanation of the approach, comparison with State-of-the-Art techniques, statement of the used metrics and software design patterns, and the name of the teams and other collaborators that are also using the software being described.

The *Technical Committee* (TC) members from the RoboCup@Home league nominate a set of candidates for the award. The *Executive Committee* (EC) elects the winner. A EC/TC member whose team is among the nominees is not allowed to vote.

1.7.6. RoboCup Design Award

Flower Robotics and the RoboCup Federation introduced an award, called the "RoboCup Design Award", to encourage research and education to focus on the importance of the design of robots. And, we continue the award for this year. Robots and/or technologies will be awarded that are well-designed not only for their performance but also for their simpleness, easiness, smoothness in daily operation and other usages. We believe that the award will promote the popularity of robotics in wider fields.

For more information about this award, please refer to http://www.robocup.org/news/34.

Chapter 2

Concepts behind the competition

A set of conceptual key criteria builds the basis for the RoboCup@Home Competitions. These criteria are to be understood as a common agreement on the general concept of the competition. The concrete rules are listed in Chapter Section 3.

2.1. Lean set of rules

To allow for different, general and transmissible approaches in the RoboCup@Home competitions, the rule set should be as lean as possible. Still, to avoid rule discussions during the competition itself, it should be very concrete leaving no room for diverse interpretation.

If, during a competition, there are any discrepancies or multiple interpretations, a decision will be made by the *Technical Committee* (TC) and the referees on site.

Note: Once the test scoresheet has been signed or the scores has been published, the TC decision is irrevocable.

2.2. Autonomy & mobility

All robots participating in the RoboCup@Home competition have to be *autonomous* and *mobile*.

An aim of RoboCup@Home is to foster mobile autonomous service robotics and natural human-robot interaction. As a consequence humans are not allowed to directly (remote) control the robot. This also includes verbally remote controlling the robot.

Furthermore, the specific tasks must not be solved using *open loop control*.

2.3. Aiming for applications

To foster advance in technology and to keep the competition interesting, the scenario and the tests will steadily increase in complexity. While in the beginning necessary abilities are being tested, tests will focus more and more on real applications with a rising level of uncertainty. Useful, robust, general, cost effective, and applicable solutions are rewarded in RoboCup@Home.

2.4. *Social relevance*

The competition and the included tests should produce socially relevant results. The aim is to convince the public about the usefulness of autonomous robotic applications. This should

be done by showing applications where robots directly help or assist humans in everyday life situations. Examples are: Personal robot assistant, guide robot for the blind, robot care for elderly people, etc. Such socially relevant results are rewarded in RoboCup@Home.

2.5. Scientific value

RoboCup@Home should not only show what can be put into practice today, but should also present new approaches, even if they are not yet fully applicable or demand a very special configuration or setup. Therefore high scientific value of an approach is rewarded.

2.6. Time constraints

Setup time as well as time for the accomplishment of the tests is very limited, to allow for many participating teams and tests, and to foster simple setup procedures.

2.7. No standardized scenario

The *scenario* for the competition should be simple but effective, available world-wide and low in costs. As uncertainty is part of the concept, no standard scenario will be provided in the RoboCup@Home League. One can expect that the scenario will look typical for the country where the games are hosted.

The scenario is something that people encounter in daily life. It can be a home environment, such as a living room and a kitchen, but also an office space, supermarket, restaurant etc. The scenario should change from year to year, as long as the desired tests can still be executed.

Furthermore, tests may take place outside of the scenario, i.e., in an previously unknown environment like, for example, a public space nearby.

2.8. Attractiveness

The competition should be attractive for the audience and the public. Therefore high attractiveness and originality of an approach should be rewarded.

2.9. *Community*

Though having to compete against each other during the competition, the members of the RoboCup@Home league are expected to cooperate and exchange knowledge to advance technology together. The *RoboCup@Home mailing list* can be used to get in contact with other teams and to discuss league specific issues such as rule changes, proposals for new tests, etc. Every team is expected to share relevant technical, scientific (and team related) information there and in its *team description paper* (see Section 3.1.4) through the team's website.

All teams are invited to submit papers on related research to the RoboCup Symposium which accompanies the annual RoboCup World Championship.

2.10. Desired abilities

This is a list of the current desired technical abilities which the tests in RoboCup@Home will focus on.

- Navigation in dynamic environments
- Fast and easy calibration and setup
  The ultimate goal is to have a robot up and running out of the box.
- Object recognition
- Object manipulation
- Detection and Recognition of Humans
- Natural human-robot interaction
- Speech recognition
- Gesture recognition
- Robot applications
  RoboCup@Home is aiming for applications of robots in daily life.
- Ambient intelligence, e.g., communicating with surrounding devices, getting information from the internet etc.

Chapter 3

General Rules & Regulations

These are the general rules and regulations for the competition in the RoboCup@Home league. Every rule in this section can be considered to implicitly include the term *"unless stated otherwise"*, meaning that additional or contrary rules in particular test specifications have a higher priority than those mentioned herein in the general rules and regulations.

3.1. Team Registration and Qualification

3.1.1. Registration and Qualification Process

Each year there are four phases in the process toward participation:

1. *Intention of Participation* (optional)
2. *Preregistration*
3. *Qualification* announcements
4. Final *Registration* for qualified teams

Positions 1 and 2 will be announced by a call on the *RoboCup@Home mailing list*. Preregistration requires a *team description paper*, a *video* and a *website*.

3.1.2. Qualification Video

As a proof of running hardware, each team has to provide a *qualification video* showing at least two from the following abilities (minimum requirement):

- Human-Robot interaction
- Navigation (safe, indoors with obstacle avoidance).
- Object detection & manipulation.
- People detection
- Speech recognition.
- speech synthesis (clear and loud).

Showing some of the following abilities is recommended:

- Activity recognition
- Complex speech recognition
- Complex action planning
- Gesture recognition

Videos should be self-explicative and designed for a general audience, showing the robot solving complex tasks. The minimum to qualify requires proving the robot is able to solve successfully at least one test of the current or last year's rulebook. For robots moving slowly, we suggest to speed-up videos. When doing so, please specify the speed factor being used (e.g. 2x, 5X, 10X). The same applies for slow motion scenes.

Please notice that the videos should not last longer than the average time for a test (max. 10 min).

Important note to Standard Platform Leagues: The qualification video must show an unmodified robot in normal operation (See Section 3.3.4).

3.1.3. Team Website

The *Team Website* should be designed for a broader audience, but also including scientific material and access to open source code being developed. Requirements are as follows:

1. **Multimedia:** Please include as many photos and videos of the robot(s) as possible.
2. **Language:** The team website has to be in English. Other languages may be also available, but English must be default language.
3. **Team:** List of the team members including brief profiles.
4. **RoboCup:** Link to the league website and previous participation of the team in RoboCup.
5. **Scientific approach:** The team website has to include research lines, description of the approaches, and information on scientific achievements.
6. **Publications:** Relevant *publications* from 5 years up to date. Downloadable publications are scored higher during the qualification process.
7. **Open source material:** Blueprints, designs, repositories or any kind of contribution to the league is highly scored during qualification process.

3.1.4. Team Description Paper

The *team description paper* (TDP) is an 8-pages long scientific paper which must have a explained description of your main research, including the scientific contribution, goals, scope, and results.

Preferably, it should also contain the following:

- the focus of research and the contributions in the respective fields,
- innovative technology (if any),
- re-usability of the system for other research groups
- applicability of the robot in the real world
- photo(s) of the robot(s)

As addendum in the 9th page (after references) please include:

- Team name
- Contact information
- Website url
- Team members' names

- photo(s) of the robot(s), unless included before.
- description of the hardware used
- Brief, compact list of *external devices* (See Section 3.6), if any.
- Brief, compact list of 3rd party reused software packages (e.g. ROS' `object_recognition` should be listed, but not OpenCV).
- [**Open Platform League only**] Brief description of the hardware ued by the robot(s).

The TDP has to be in English, up to eight pages in length and formatted according to the guidelines of the RoboCup International Symposium without altering margins or spacing. It goes into detail about the technical and scientific approach.

Please notice that, during qualification process, TDP will be scored by its scientific value, novelty and contributions.

3.1.5. Qualification

During the *qualification process* a selection will be made by the *Organizing Committee* (OC) Taken into account and evaluated in this decision process are:

- The content on the team website, scoring higher publications and open source resources;
- the number of abilities shown in the qualification video,
- the complexity of the tasks shown in the qualification video, and
- the scientific value, novelty and contributions in the *team description paper*.

(Additional) evaluation criteria are:

- the performance in previous competitions,
- the relevant scientific contributions and publications, and
- the contributions to the RoboCup@Home league.

Important note to Standard Platform Leagues: Only unmodified robots may compete in Standard Platform Leagues. Any *slight* modification made to the robot found in the Qualification Material will automatically disqualify the team, for which registration to the international competition will not be possible (See Section 3.3.4).

3.2. Scenario

The tests take place in the *RoboCup@Home arena*. In addition, particular tests are situated outside the arena, e.g., in a previously unknown public place. The following rules are related to the *RoboCup@Home arena* and its contents.

3.2.1. RoboCup@Home arena

The *RoboCup@Home arena* is a realistic home setting (apartment) consisting of inter-connected rooms like, for instance, a living room, a kitchen, a bath room, and a bed room. Depending on the Local Organization, there may be multiple apartments which may be different to each other. Robot must be prepared to perform any task in any arena, not the same arena every time.

The arena is decorated and dressed to resemble a home in which one could live, with as much of the necessities and decorations one might find in a normal home. Please do note that what is considered as "normal" may greatly vary by culture and on the location where the RoboCup event is hosted. For some examples on items one may find in the arena, see Section E

3.2.2. Walls, doors and floor

The indoor home setting will be surrounded by high and low *walls*. These walls will be built up using standard fair construction material.

1. **Walls:** Walls have a minimum height of 60 cm. A maximum height is not specified, but should be chosen so that the audience is able to watch the competition.
   Walls will be fixed and are likely to be not modified during the competition (see Section 3.2.4).
2. **Doors:** There will be at least two entry/exit *doors* connecting the outside of the scenario. These doors are used as starting points for the robots (see Section 3.8.9). There will be also another door inside the scenario with a handle (not a knob) between any two rooms. Doors with handle (not a knob) may be closed at any time, it is expected robots be able to open them.
3. **Floor:** The floor of the arena as well as the doorways of the arena are even. That is, there will be no significant steps or even stairways. However, minor unevenness such as carpets, transitions in floor covering between different areas, and minor gaps (especially at doorways) must be expected.
4. **Appearance:** Floor and walls are mainly uni-colored but can contain texture, e.g., a carpet on the floor, or a poster or picture on the wall.
   Although being unlikely at the moment, transparent elements are also possible.

3.2.3. Furniture

The arena will be equipped with typical objects (furniture) that are not specified in quantity and kind. The minimal configuration consists of

- a small dinner table with two chairs,
- a couch,
- an open cupboard or small table with a television and remote control,
- a cupboard or shelf (with some books inside), and
- a refrigerator in the kitchen (with some cans and plastic bottles inside).

A typical arena setup is shown in Figure 3.1a.

3.2.4. Changes to the arena

Since the robots should be able to function in the real world the scenario is not fixed and might change without further notice.

1. **Major changes:** The arena is meant to be a simulated apartment. The furniture might be moved around between tests. This includes furniture that is a named location (see Section 3.2.8). As in a normal home, furniture is not very likely to move from one room to

(a) Typical arena **(b)** Typical objects

Figure 3.1.: Scenario examples: (a) a typical arena, and (b) typical objects.

another and is unlikely to be moved to the other side of a room. However, a couch or table may be rotated, moved to its side etc. Walls will stay in place and rooms will not change function. Passages might be blocked and cleared. One hour before a test slot begins no *major changes* will be made. This time will be shortened in the future.

2. **Minor changes:** In contrast to major changes, *minor changes* like, for instance, slightly moved chairs cannot be avoided and may happen at any time (even during a test).

3.2.5. Objects

Some tests in the RoboCup@Home league involve object manipulation and recognition. These *objects* resemble items usually found in household environments like, for instance, soda cans, coffee mugs or books. An example of objects used in a previous competition can be seen in Figure 3.1b.

Objects are divided in five main groups:

1. ***Known objects*:** Objects with no noticeable difference among peers. *Known objects* tend to be artificial and regular shaped, such as coke cans, beer bottles, cereal boxes, etc. A set of copies of these objects is provided before the competition for training.
2. ***Alike objects*:** Objects with slight differences among peers (e.g. color, size, shape). *Alike objects* tend to be natural and similar to each other, but not equal; for example: apples, bananas, rags, etc. A specimen of these objects is provided before the competition for training.
3. ***Containers*:** Objects which can contain, transport or be filled with other objects or their content, such as baskets, bowls, bags, trays, etc. . As with *known objects*, *containers* are known beforehand with no noticeable difference among peers, and a copy is provided before the competition for training.
4. ***Special objects*:** Objects require a proper identification and special handling (not necessarily grasping), operation or interaction for accomplishing a particular task. Examples of special objects are: door handles, chairs, walking sticks, poles, etc. Notice that a copy of these objects may not be available beforehand for previous training.

5. ***Unknown objects*:** Any other object that is not known beforehand but can be grasped or handled.

The following general rules for objects apply:

1. **Object category:** Each object will be assigned to an *object category*. The objects "apple" and "banana" may be of class "fruits" for example.
2. **Object (category) locations:** An *object location* object will be assigned to each *object category*. For example, Objects categorized as "fruits" may be usually found on the "kitchen table", and unknown objects "unknown" may be usually found on the "trash bin".
3. **Announcement:** The TC makes the set of *objects*, including their names, categories, and usual locations; available during the setup days.
4. **Placement:** Unless stated otherwise, in manipulation tasks, the objects will be positioned at *manipulation locations* and less than 15 cm away from the border of the surface they are located at. There will be at least 5 cm space around each object.

Important note: It is not allowed to modify any of the objects provided for training. Also, teams are not allowed to keep more than 5 the objects provided for training at a time nor retaining it for more than one hour.

Containers

The TC will provide at least three different types of containers to be used in the tests.

- **Pouring containers:** Such as a bowls, glasses, or other objects in which liquids and grains can be poured.
- **Storage containers:** Such as bags or boxes in which objects can be stored or retrieved. Bags used during the competition are rigid and with clearly visible standing handles; more likely made of paper and in bright colors (See Figure 3.2a).
- **Transport containers:** Such as trays in which objects can be neatly arranged for transport.

Although there are no restrictions on a container size, appearance or weight; however, it can be expected that the selected containers be lightweight, with handles, and easily manipulable by a human using either one or both hands.

(a) Bright-colored paper bags **(b)** Cereal bowls **(c)** Serving tray

Figure 3.2.: Example of object containers

Custom containers. It is allowed that a team provide a *custom container* adapted to be used by the robot, considering the following:

1. Custom containers must be approved by the TC during during the *Robot Inspection* (see Section 4.4).
2. Custom containers must *not* have any kind of artificial marks, sensors, or electronic devices.
3. Penalties may apply for the use of custom containers. The TC may establish special penalties during the *Robot Inspection*. The default penalties applicable to any task involving a container are as follows.
   - Special color on an otherwise unmodified two-hand manipulable container: 75% of the points.
   - Special color on an otherwise unmodified single-hand manipulable container: 50% of the points.
   - Specially designed or adapted two-hand manipulable container (e.g. special handles): 50% of the points.
   - Specially designed or adapted single-hand manipulable container (e.g. special handle): 25% of the points.
   - Two-hand manipulable container adapted to be used *single-handed*: 25% of the points.
   - On-robot mounted container: 0 points.

   Notes: Trays are considered two-hand manipulable containers, while most bowls and dishes are considered single-hand manipulable container unless they are too big. Color patterns are allowed as long as they look natural (e.g. *barber sign colored* handles are allowed, but black and white bar-code like handles are not). Penalties does not stack, the most meaningful modification is considered.

Predefined objects

The TC will compile a list of at least 10 objects (including both *known objects* and *alike objects*) which will be available for training. There are no restrictions on an object size, appearance or weight; however, it can be expected that the selected objects are easily manipulable by a human using a single hand.

Note that, any object not previously announced by the TC is automatically considered an unknown object for scoring purposes (e.g. ornamentation).

3.2.6. Predefined locations

Some tests in the RoboCup@Home league involve *predefined locations*. These may include places like a "bookshelf" or a "dining table", as well as certain objects such as a "television", or the "front door".

1. **Definition:** The TC will compile a list of predefined locations. There are no restrictions on which parts of the arena will be selected as a predefined location.
2. **Location classes:** Each location will be assigned to a *location class*. The objects "couch" and "arm chair" may be of class "seat" for example.

3. **Announcement:** The TC makes the set of locations (and their names and classes) available during the setup days.
4. **Position:** The positions of locations are *not* necessarily fixed (see Section 3.2.4).
5. **Manipulation locations:** The TC will mark at least 20 locations out of the set of predefined locations as being *manipulation locations*. Whenever a test involves manipulation, the object to manipulate will be placed at one of the manipulation locations.

3.2.7. Predefined rooms

Some tests in the RoboCup@Home league involve *predefined rooms*.

1. **Definition:** The TC will compile a list of room names.
2. **Announcement:** The TC makes the set of rooms available during the setup days.

3.2.8. Predefined (person) names

Some tests in the RoboCup@Home league involve *predefined names* of people.

1. **Definition:** The TC will compile a list of 20 predefined names. The names are 50 % male and 50 % female, and taken from the (current) most common first names in the United States.
   In order to ease speech recognition, it is tried to select names to be phonetically different from each other.
2. **Announcement:** The TC makes the set of names available during the setup days.
3. **Assignment:** When a test involves interacting with persons (using a person's name), all involved persons are assigned names by the referees before the test.

Typical names are, for example, James, John, Robert, Michael and William as male names; Mary, Patricia, Linda, Barbara and Elizabeth as female names.

3.2.9. Wireless network

For wireless communication, an *arena network* is provided. The actual infrastructure depends on the local organization.

- To avoid interference with other leagues, this *arena network* has to be used for communication only. It is not allowed to use the above or any other WiFi network for personal use at the venue.
- During the competitions, only the active team is allowed to use the *arena network*.
- The organizers cannot guarantee reliability and performance of wireless communication. Therefore, teams are required to be ready to setup, start their robots and run the tests even if, for any reason, network is not working properly.

Preferred situation:

- The *arena network* consists of of several Virtual Local Area Networks (VLANs), one for each team.

- The traffic from the robot inside the arena is separated into the corresponding team's VLAN as soon as possible, e.g. at the wireless acces point.This may require that each team has it's own SSID, each of which gets routed into the corresponding VLAN. Each team has a network cable routed to their team area, which is also connected to the teams VLAN. On this cable, the team can set up their own router/switch/hub etc. which will be inside the team's VLAN. This way, one team's traffic and devices are completely separated from any other team, while any team can set up their own DHCP server etc. if they desire.
- An Internet connection is preferably also available for every team.

Each team has to bring its own LAN hub/switch and cables for routing inside the team area.

In case the *arena network* is not functioning at the end of the first setup day, teams are allowed to set up their own networking equipment and wireless networks.

Important note: Different countries have different regulations for wireless equipment and the *arena network* has to obey these. It is up to the teams to have networking equipment that also adheres to these regulations. For example, if due to local regulations various WiFi channels are prohibited, it is a team's responsibility to be able to use different, allowed channels.

Important note: Any unapproved wireless device may be removed by the TC at any time.

3.3. Robots

3.3.1. Autonomy & Mobility

Robots that participate in the RoboCup@Home league need to be *autonomous* and *mobile*. Any deviations reported to the TC, may result in a penalty for the team (see Section 3.10.2).

3.3.2. Number of robots

1. **Registration:** The maximum *number of robots* per team that can be registered for the competitions is *two* (2).
2. **Regular Tests:** Only one robot is allowed per test. For different tests different robots can be used.
3. **Open Demonstrations:** In the *Open Challenge* and the *Finals* both robots can be used simultaneously.

3.3.3. Appearance and safety

Robots should have a nice product-like appearance, be safe to operate & be around and should not annoy its human users. The following rules apply to all robots and are part of the *Robot Inspection* test (see Section 4.4).

1. **Cover:** The robot's internal hardware (electronics and cables) should be covered in an appealing way. The use of (visible) duct tape is strictly prohibited.
2. **Loose cables:** There may not be any loose cables hanging out of the robot.
3. **Safety:** The robot may not have sharp edges or other things that could severe people.
4. **Annoyance:** The robot should not permanently make loud noises or use blinding lights.

5. **Marks:** The robot may not exhibit any kind of artificial marks or patterns.
6. **Driving:** To be safe, the robots should be careful when driving in a direction it cannot sense, for example.

3.3.4. Standard Platform Leagues

RoboCup@Home features two Standard Platform Leagues adhering to the rules listed above.

Modifications

The idea of having standardized platform is to allow teams to compete in equality of conditions by eliminating all hardware-dependent variables. Therefore, both Standard Platform Leagues are considered as *closed hardware design*, meaning that and modifications and alterations to the robots are strictly forbidden; including, but not limited to attaching, connecting, plugging, gluing, and taping components into and onto the robot, as well as modifying or altering the robot structure. Voiding this rule leads to immediate disqualification from the competition and penalty for the team (see Section 3.10.2).

All robots competing in a Standard Platform League will be inspected by TC during the *Robot Inspection* test (see Section 4.4), who will verify that the robot is in proper state for the competition, presenting no alterations and in neat condition. In addition, EC and TC members may request re-inspection of a SPL robot at any time during the competition.

Clothing, coloring, and stickers: Robots competing in a Standard Platform League are allowed to "wear" clothes, as well as have stickers (e.g., a sticker exhibiting the logo of an sponsor). Painting the robot with another color or design is also allowed. However, teams must keep in mind that no artificial markers are allowed when personalizing the appearance or a robot. This includes, but is not limited to bar codes, QR codes, OpenCV markers, fluorescent and phosphorescent colors, and reflective stickers. Finally, is important to remark that teams should contact first the robot's vendor and review the lease contract to verify they are authorized to alter the robot's appearance.

Domestic Standard Platform League

The characteristics of the Toyota Human Support Robot are detailed below.

- Aimed at human support tasks, elderly care et cetera
- Omni-directional base, maximum speed 0.8km/h
- 1 arm with multifunctional gripper through a vacuum pad. The wrist is equipped with a force-torque sensor. Capable of lifting 1.2kg.
- RGB-D, stereo cameras and wide-angle camera
- Display mounted in head, separate tablet interface
- Access to cloud-based services
- Equipped with a microphone array
- Gravity compensated arm
- Height-adjusting torso

Social Standard Platform League

The characteristics of the Softbank Robotics/Aldebaran Pepper are detailed below.

- Aimed at social interaction, public environments, explainable artificial intelligence
- Omni-directional base, maximum speed 3km/h
- 2 arms mostly intended for social gesturing.
- 3D and 2 HD cameras
- Equipped with a built-in tablet
- Access to cloud-based services
- Equipped with a 4-microphone array in the head
- Emotion recognition by voice and images
- Emotion engine to adapt it's attitude

3.3.5. Robot Specifications for the Open Platform League

Robots competing in the RoboCup@Home Open Platform League must comply with security specifications in order to avoid causing any harm while operating in human environments.

Size and weight of robots

1. **Dimensions:** The dimensions of a robot should not exceed the limits of an average door, which is 200 cm by 70 cm in most countries.
   The TC may allow the qualification and registration of larger robots, but due to the international character of the competition it cannot be guaranteed that the robots can actually enter the arena. In case of doubt, contact the local organization.
2. **Weight:** There is no specific weight restriction. However, the weight of the robot and the pressure it exerts on the floor should not exceed local regulations for the construction of buildings which are used for living and/or offices in the country where the competitions is being held.
3. **Transportation:** Team members are responsible for quickly moving the robot out of the arena. If the robot cannot move by itself (for any reason), the team members must be able to transport the robot away with an easy and fast procedure.

Emergency stop button

1. **Accessibility and visibility:** Every robot has to provide an easily accessible and visible *emergency stop* button.
2. **Color:** It must be coloured red, and preferably be the only red button on the robot. If it is not the only red button, the TC may ask the team to tape over or remove the other red button.
3. **Robot behavior:** When pressing this button, the robot and all parts of it have to stop moving immediately.
4. **Inspection:** The emergency stop button is tested during the *Robot Inspection* test (see Section 4.4).

Start button

1. **Requirements:** As stated in Section 3.8.8, teams that aren't able to carry out the default start signal (opening the door) have to provide a *start button* that can be used to start tests. The team needs to announce this to the TC before every test that involves a start signal, including *Robot Inspection*.
2. **Definition:** The start button can be any "one-button procedure" that can be easily executed by a referee. This includes, for example, the release of the *emergency button* (Section 3.3.5), a hardware button different from the *emergency button* (e.g., a green button), or a software button in a Graphical User Interface.
3. **Inspection:** It is during the the *Robot Inspection* test (see Section 4.4) that the procedure for the start button, if needed, is announced to the TC and inspected. The start button for a robot should be the same for all the tests.
4. **Penalty for using start button:** If a team needs to use the start button in a test where opening the door is the start signal, it may receive a penalty (see Section 3.8.8).

Audio output plug

1. **Mandatory plug:** Either the robot or some external device connected to it *must* have a *speaker output plug*. It is used to connect the robot to the sound system so that the audience and the referees can hear and follow the robot's speech output.
2. **Inspection:** The output plug needs to be presented to the TC during the *Robot Inspection* test (see Section 4.4).
3. **Audio during tests:** Audio (and speech) output of the robot during a test have to be understood at least by the referees and the operators.
   - It is the responsibility of the teams to plug in the transmitter before a test, to check the sound system, and to hand over the transmitter to next team.
   - Do not rely on the sound system! For fail-safe operation and interacting with operators make sure that the sound system is not needed, e.g., by having additional speakers directly on the robot.

Appearance

Open Platform Robots should have a neat appearance that resembles more a safe and finished product than an early stage prototype, paying special attention in completely cover the robot's internal hardware (electronics and cables) in an appealing way. Although covering the robot's internal hardware with a T-Shirt is not forbidden (for now) it is strongly unadvised.

3.4. Data Recording

In order to benchmark robots and software outside the RoboCup@Home arena, the teams are asked to contribute to a public dataset. This will consist of audio, imagery and other data obtained and generated by the robots during RoboCup@Home tests. Contributing to this dataset gives a small bonus as an incentive. The bonus will be proportional to the points gathered normally: if 50% of points are gathered, 50% of the data collection points are awarded.

3.4.1. Collected data

During a test, specific data can be gathered and stored on a USB stick. After all attempts at a test are made, the USB stick must be given to the TC, which will copy the data to the public dataset. The recordings themselves are not used for scoring and may be post-processed manually to be more useful, before handing over to the TC. Not all types of data are interesting for each test and thus each test will list which data to record.

- **Audio:** A .wav file of conversation or commands given by any operator and the result of the automatic speech recognition, if applicable. The recording must be made of the same signals that are input to the automatic speech recognition software.
  - **Format:** TeamName_SensorName_Timestamp.wav
  - **Format:** PCM Wav 44.1 kHz 16 bit stereo
- **Commands:** A text file with the commands as received by the robot. This may be the output of speech recognition or the outcome of any form of bypassing it via the CONTINUE rule (see Section 3.9.1). Include a timestamp and then the command.
  - **Format:** TeamName_commands_Timestamp.csv
  - **Format:** csv-file. First column has command timestamp, second column the command in "quotes".
- **Images:** 2D and/or 3D RGB(D) images from the robot's camera(s) while doing any sort of recognition task. Record the full field of view.
  - **Color images:**
    - **Filename:** TeamName_SensorName_Timestamp_rgb.png
    - **Format:** Standard PNG 24bit
  - **Depth images:**
    - **Filename:** TeamName_SensorName_Timestamp_depth.png
    - **Format:** Standard PNG 16bit grayscale
- **Mapping data:** Record the data the robot uses for mapping its surroundings and obstacle avoidance plus the resulting map. For many robots this will be 2D laser scans of an Laser Range Finder but other means are possible.
- **Plans:** Any plan generated by the robot. This includes navigation paths, arm trajectories and action plans. If possible, plans are preferably annoted with whether is was succesfully executed or not.

For ROS-based robots, the most convenient data format for mapping data (laser scans, occupancy grids etc.) and motion plans are their ROS messages recorded into a ROS Bag file. This ROSBag should then contain:

- **Laser scans:** sensor_msgs/LaserScan
- **Path(s):** nav_msgs/Path
- **Map(s):** nav_msgs/OccupancyGrid
- **Robot pose:** geometry_msgs/PoseStamped
- **Transformation tree:** tf2_msgs/TFMessage or equivalent
- **Odometry:** nav_msgs/Odometry

Although not all robots use ROS, this serves as a guideline of the type of data that may be interesting for others. The RoCKIn robot competition provides a conversion tool that converts to ROS Bag files: http://rockinrobotchallenge.eu/rockin_d2.1.3.pdf, section 3.4 and https://github.com/rockin-robot-challenge/benchmark_and_scoring_converter

3.5. External devices

1. **Definition:** Everything which is not part of the robot is considered an *external device*.
2. **Inspection:** In general, external devices are not allowed unless presented and explained to the *Technical Committee* (TC) during the *Robot Inspection* test (see Section 4.4).
3. **Supervision:** In regular tests, external devices may only be used under supervision by referees and after approval by the TC. The devices have to be brought to the arena for every test, and removed quickly after the test.
4. **Open demonstrations:** For the *Open Challenge* and the *Finals*, external devices are allowed, still their use needs to be announced beforehand.
5. **Wireless devices:** All *wireless devices* including bluetooth devices, walkie-talkies, and anything else that uses an RF signal to operate need to be announced to the *Organizing Committee* (OC). The use of any wireless device not approved by the TC is strictly prohibited.
6. **Artificial landmarks:** *Artificial landmarks* and *markers* are not allowed.
7. **Computing devices:** External computers for decentralized computations are allowed, please see Section 3.6.
8. **Wireless LAN:** The use of networks other than the *arena network* (see Section 3.2.9) is strictly prohibited.
9. **External device for audio processing:** An external speech processing device is allowed. The device is only allowed to connect the mixer's audio line out. The device can be used for sending the raw signal to the robot, processing it on the device, or sending the signal to a third-party's ASR service.
10. **External microphones:** *External microphones*, hand microphones, and headsets are not allowed in OPL. Although using an *on-board microphone* is recommended in DSPL and SSPL, using the following *official microphone* is allowed as a backup.
    - **DSPL/SSPL only:** In order to make the audience to catch what is spoken to the robot, the speaker is supposed to use the official microphone to speak to the robot. The official microphone is used for the tasks inside the arena except SSL-related tests (*Speech and Person Recognition*). Outside the arena, the official microphone is not used.

3.6. External computing

Robots are allowed to use some form of external computing, for example in the form of so-called "Cloud services" and/or "Internet API's" etc.

1. **Definition:** Computing resources that are not physical part of the robot are *external computing resources*.

2. **Inspection:** In general, external computers are not allowed unless explained to and allowed by the *Technical Committee* (TC). A team must announce to the TC at least 1 month in advance the external computing resources they want to use, for what purpose and how to reach the resources (e.g. specify the URL or IP address and port). Inspected software must meet the following **requirements:**
   - The software must be open source (BSD/GPL/etc), or
   - Detailed information about the propietary product must be provided (e.g. vendor, patent number, licencing, pricing, etc.), as well as publishing the interface for scientific use.

   All relevant information must be specified in the team description paper.
3. **Connection:** The robot may connect to *external computing resources* via a network connection, e.g. the Internet. The competition organisation cannot make any guarantees concerning availability, connectivity and performance of the connection. The robot should still be functional (albeit limited perhaps) if the *external computing resources* cannot be used for some reason. This is the team's responsibility.
4. **Autonomy:** The robot has to maintain full autonomy when using *external computing resources*, meaning there may not be a human giving the robot any kind of instructions via *external computing resources*. It is up to the team to prove to the *Technical Committee* (TC) that there was no cheating introduced via the *external computing resources*. For example, the use of Amazon Mechanical Turk to classify and recognize objects during a competition will be considered cheating, since effectively a human will do the classification. Remote control or tele-operation is also considered cheating.
5. **Availability:** The resources must be publicly available, for use by robots of other teams, well before and after the competition.
6. **Recognition:** In case the resources are not developed by the team itself, the creators must be properly credited in the Team Description Paper (See Section 3.1.4).
7. **Limit:** A robot is limited to use up to 5 *external computing resources*.

Remark: Teams are allowed to use their own software in the external computing devices (not only cloud services). This software must be publicly available to other teams for scientific purposes (evaluation, test, and benchmarking), as well as for TC for inspection. Although open-sourcing the software is not mandatory, this practice is advised and encouraged by the league.

3.7. Organization of the competition

3.7.1. Stage system

The competition features a *stage system*. It is organized in two stages each consisting of a number of specific tests. It ends with the *Finals*.

1. **Stage I:** The first days of the competition will be called *Stage I*. All qualified teams can participate in *Stage I*. Stage I comprehends a set of *Ability Tests*, an *Integration Test*, and an audience demonstration called *Following & Guiding*. Those *Proficency Tests* (*Ability Tests*, and *Integration Test*) are performed multiple times (See Section 3.7.4).

2. **Stage II:** The best *50% of teams with full integrated capabilities*[1] (after Stage I) advance to *Stage II*. Here, more complex abilities or combinations of abilities are tested. In order to advance to Stage II a team must successfully solve 3 out of *Proficency Tests* in Stage I. The *Open Challenge* is the open demonstration in Stage II.
3. **Final demonstration:** The best *two teams* of each league, the ones with the highest score after Stage II, advance to the final round. The final round features only a single open demonstration.

In case of having no considerable score deviation between a team advancing to the next stage and a team dropping out, the TC may announce additional teams advancing to the next stage.

3.7.2. Number of tests

None of the tests is mandatory, except for the *Robot Inspection* test (see Section 4.4). However, in order to participate in the finals, a team must have participated in at least one test of the Stage II.

3.7.3. Schedule

1. **Tests:** The *Organizing Committee* (OC) provides schedules for all tests and teams.
2. **Participation is default:** Teams have to indicate to the *Organizing Committee* (OC) in which tests they are *not* going to participate. Without such indication, they are automatically added to all test schedules and may receive a penalty when not attending (see Section 3.10.1).
3. **Slots:** The tests will be held in *test slots* of approximately two hours.
4. **Preparation:** The *Organizing Committee* (OC) provides schedules for all teams to organize the access to the arena between test slots. In these *preparation slots* the teams may conduct calibration procedures, remap the arena if necessary, or conduct test runs. Preparation slots are inserted whenever possible, but may not be available before all test slots.
5. **Arena access:** One hour before a test slot, only the teams participating in that slot are allowed in the arena. This rule only applies when not having organized *preparation slots*.

3.7.4. Score system

1. **Stage I:** The maximum total score (excluding special penalties and bonuses) in *Stage I* is *1150 points*.
   1.1. ***Proficency Tests*:** Each proficiency test is attempted three times. The maximum total score is calculated as the average of the best two attempts for that test.
2. **Stage II:** Test in *Stage II* are rewarded on a task-solved scoring basis.
   2.1. Each test but the *Open Challenge* has a main task. The base score for solving the main task is *250 points*.
   2.2. The maximum score for *Open Challenge* is *250 points*.
   2.3. Optionals and subtasks add bonus points to the main task score.

[1] If the total number of teams is less than 12, up to 6 teams may advance to Stage II

3. ***Finals*:** Final score is normalized and special evaluation is used
4. **Special tests:** Tests may specify a maximum total score deviating from the general maximum total scores.
5. **Minimum score:** The minimum total score per test in *Stage I* and *Stage II* is *0 points*. That is, if the total score for a test is below zero, the team does not receive any points.
6. **Penalties:** An exception to the *minimum score* rule are penalties. Both penalties for not attending (see Section 3.10.1) and extraordinary penalties (see Section 3.10.2) can cause a total negative score.
7. **Partial scores:** All tests—except for the open demonstrations—are rewarded on a partial scoring basis.
   7.1. Tests are split into designated parts.
   7.2. Each part is assigned a certain number of points.
   7.3. A team that successfully passes a designated part of the test receives points for that part.
   7.4. In case of partial success, referees (and TC members) may decide to only award a percentage instead of the full partial score.
   7.5. The total score for a test is the sum of partial scores.
   7.6. Partial scores can be negative (e.g. to penalize failures etc.).

3.7.5. Open Demonstrations

1. **Stage II:** The *Open Challenge* is the open demonstration in *Stage II*.
   1.1. To participate in the *Open Challenge*, a team needs to participate in at least one regular *Stage II* test.
   1.2. Teams can demonstrate freely chosen abilities.
   1.3. The performance is evaluated by a jury consisting of the *Technical Committee* (TC).
   1.4. The *Open Challenge* is described in Section 6.2.
2. ***Finals*:** The competition ends with a final demonstration.
   2.1. The concept of the final demonstration is the same as that of the *Open Challenge*, but the performance evaluation is different.
   2.2. The are two juries—an *external* consisting of three or more people not from the RoboCup @Home league, and an *internal* formed by the *Executive Committee* (EC). Both juries have different sets of evaluation criteria.
   2.3. Members of the external jury are selected by the *Executive Committee* (EC) on site.
   2.4. The demonstration in the *Finals* does not have to be different from the one shown in the *Open Challenge*. It does not have to be the same either.

3.8. Procedure during Tests

3.8.1. Safety First!

1. **Emergency Stop:** At any time when operating the robot inside and outside the scenario the owners have to stop the robot immediately if there is a remote possibility of dangerous behavior towards people and/or objects.

2. **Stopping on request:** If a referee, member of the Technical or Organizational committee, an Executive or Trustee of the federation tells the team to stop the robot, there will be no discussion and the robot has to be stopped *immediately*.
3. **Penalties:** If the team does not comply, the team and its members will be excluded from the ongoing competition immediately by a decision of the RoboCup@Home *Technical Committee* (TC). Furthermore, the team and its members may be banned from future competitions for a period not less than a year by a decision of the RoboCup Federation Trustee Board.

3.8.2. Maximum number of team members

1. **Regular Tests:** During a regular test, the maximum number of team members allowed inside the arena is *one* (1). The only exceptions are tests that require for more team members in the arena.
2. **Setup:** During the setup of a test, the number of team members inside the arena is not limited.
3. **Open Demonstrations:** During the *Open Challenge*, and the *final demonstration* (Finals), the number of team members inside the arena is not limited.
4. **Moderation:** During a regular test, one team member *must* be available to host and comment the event (see Section 3.8.13).

3.8.3. Fair play

Fair Play and cooperative behavior is expected from all teams during the entire competition, in particular:

- while evaluating other teams,
- while refereeing, and
- when having to interact with other teams' robots.

This also includes:

- not trying to cheat (e.g. pretending autonomous behavior where there is none),
- not trying to exploit the rules (e.g. not trying to solve the task but trying to score), and
- not trying to make other robots fail on purpose.
- not modifying robots in standard platforms.

Disregard of this rule can lead to penalties in the form of negative scores, and disqualification for a test or even for the entire competition.

3.8.4. Expected Robot's Behavior

Unless stated otherwise, it is expected that the robot always behave and react in the same way a polite and friendly human being would do. This applies also to how robots should address the problems in order to solve the assigned task, including addressing people, serving meals, storing the groceries, cleaning, arranging stuff, etc. As rule of thumb, ask your closest non-scientist neighbor to solve the task and take notes.

Keep in mind that one of the goals in RoboCup @Home is to have robots interacting with real people in domestic environments. This means that the average user will not know any specific procedure on how to operate the robot, but they will interact with it as with any other human being.

3.8.5. Robot Autonomy and Remote Control

1. **No touching:** During a test, the participants are not allowed to make contact with the robot(s), unless it is in a "natural" way and/or required by the test specification.
2. **Natural interaction:** The only allowed means to interact with the robot(s) are gestures and speech.
3. **Natural commands:** Only general instructions are allowed. Anything that resembles direct control is prohibited.
4. **Remote Control:** Remotely controlling the robot(s) is strictly prohibited. This also includes pressing buttons, or influencing sensors on purpose.
5. **Penalties:** Disregard of these rules can lead to penalties in the form of negative scores, and disqualification for a test or even for the entire competition.

3.8.6. Collisions

1. ***Touching*:** Robots are allowed to gently *touch* objects, items and humans. They are not allowed to crash into something. The "safety first" rule (Section 3.8.1) supercedes all other rules.
   - It *is* allowed however to *functionally* touch an item with e.g. the base.

   The OC/TC/EC and the RoboCup Trustees all have the right to immediately stop a robot, and to disqualify a team for the duration of the competition, or longer, in case of *dangerous* behavior. Furthermore, referees can recommend to disqualify a team in which case EC/TC decides.
2. ***Major collisions*:** If a robot crushes into something during a test, the robot is immediately stopped. Additional penalties may apply.
3. **Robot-Robot avoidance:** If two robots encounter each other, they both have to actively try to avoid the other robot.
   3.1. A robot which is not going for a different route within a reasonable amount of time (e.g., 30 s) is removed.
   3.2. A non-moving robot blocking the path of another robot for longer than a reasonable amount of time (e.g., 30 s) is removed. In this context, "moving" refers to any kind of motion or action required in the test. For example, a robot standing still but manipulating an object does not need to stop manipulating and move away, even when blocking the way of another robot for the duration of the manipulation.

3.8.7. Removal of robots

Robots not obeying the rules are stopped and removed from the arena.

1. It is the decision of the referees and the TC member monitoring the test if and when to remove a robot.

2. When told to do so by the referees or the TC member monitoring the test, the team has to immediately stop the robot, and remove it from the arena without disturbing the ongoing test.

3.8.8. Start signal

Different tests are started in different ways, according to what would make the most sense in the application setting. Before a test starts, robots are waiting in a queue, sometimes accompanied by a team member.

The various start methods are described below:

1. **Door opening:** The robot is waiting behind the door, outside the arena (accompanied by a team member). The test attempt starts when a referee (not a team member) opens the door.
2. **Start button:** If the robot is not able to automatically start after opening the door, the team may start the robot using a start button.
   2.1. Using a start button needs to be announced to the referees. It is the responsibility of the team to do so before the test starts.
   2.2. There may be penalties for using a start button in some tests
3. **Called by name:** A number of robots is waiting inside the arena, unaccompanied by team members. The referee approaches the robot, calls it by its name and gives the robot a command. e.g. "R2D2, start" or "C3PO, continue". Other waiting robots must not respond.

3.8.9. Entering and leaving the arena

1. **Start position:** Unless stated otherwise, the robot starts outside of the arena.
2. **Entering:** The robot has to autonomously enter the arena.
3. **Success:** The robot is said to *have entered* when the door used to enter can be closed again, and the robot is not blocking the passage.

3.8.10. Gestures

Hand gestures may be used to control the robot in the following way:

1. **Definition:** The teams define the hand gestures by themselves.
2. **Approval:** Gestures need to be approved by the referees and TC member monitoring the test. Gestures should not involve more than the movement of both arms. This includes e.g. expressions of sign language or pointing gestures.
3. **Instructing operators:** It is the responsibility of the team to instruct operators.
   3.1. The team may only instruct the operator when told to so by a referee.
   3.2. The team may only instruct the operator in the presence of a referee.
   3.3. The team may only instruct the robot for as long as allowed by the referee.
   3.4. When the robot has to instruct the operator, it is the robot that instructs the operator and *not* the team. The team is not allowed to additionally guide the operator, e.g., tell the operator to come closer, speak louder, or to repeat a command.

3.5. The robot is allows to instruct the operator at any time.

4. **Receiving gestures:** Unless stated otherwise, it is not allowed to use a speech command to set the robot into a special mode for receiving gestures.

3.8.11. Referees

1. **Setup:** Unless stated otherwise, each test is monitored by two referees and one member of the *Technical Committee* (TC).
2. **Selection:** The two referees
   - are chosen by EC/TC/OC,
   - are announced together with the schedule for the test slot,
   - and have to referee all teams in that slot.
   - Referees may not be from one of the teams in the slot.
3. **Not showing up:** Not showing up for refereeing (on time) will result in a penalty (see Section 3.10.2).
4. **TC monitoring:** The referee from the TC acts as a main referee.
5. **Referee instructions:** Right before each test, referee instructions are conducted by the TC. The referees for all slots need to be present at the arena where the referee instructions are taking place.When and where referee instructions are taking place is announced together with the schedule for the slots.

3.8.12. Operator

1. **Default operator:** Unless stated otherwise, robots are operated by the monitoring TC member, a referee, or by a person selected by the TC.
2. **Fallback/custom operator:** If the robot fails to understand the command given by the default operator, the team may continue with a custom operator.
   - The custom operator may be any person chosen by the team (and willing to do so); including the referees or the monitoring TC member.
   - A penalty may be involved when using a custom operator.

3.8.13. Moderator

1. **Providing a moderator:** For each regular test (i.e., not for the open demonstrations), all participating teams need to provide a team member as moderator for the duration of their performance.
2. **Responsibilities:** The moderators have to:
   - explain the rules of the test,
   - comment on the performance of their team,
   - not interfere with the performance,
   - speak in English,
   - and obey the instructions by the monitoring TC member.
3. **Competitive tests:** In competitive tests (tests in which two teams directly compete against each other), the moderation has to be done by the two teams together.

3.8.14. Time limits

1. **Stage I:** Unless stated otherwise, the time limit for each test in *Stage I* is *5 minutes*.
2. **Stage II:** Unless stated otherwise, the time limit for each test in *Stage II* is *10 minutes*.
3. **Setup time:** Unless stated otherwise, all time specifications, e.g., setup time and time for instructing operators, are within the total test time.
4. **Scores:** When the time is up, the team has to immediately remove their robot(s) from the arena; no more points can be scored. In special cases, the monitoring TC member may ask the team to continue the test for demonstration purposes (after time is up, points cannot be scored).

3.8.15. Restart

1. **Stage 1** has no restarts but features multiple attempts at a test. If a robot fails during an attempt, the attempt ends. A robot has several (ideally 3, depending on available time in the schedule) attempts for each test. An attempt cannot be restarted. E.g. if a robot fails halfway through an attempt at the Help-me-Carry test, the attempt is over, the robot is moved out of the test area and may prepare for the remaining attempts at the test.
2. **Stage 2** does have restarts for all tests but the Open Challenge:
   2.1. **Number of restarts:** A team may request one (1) restart during a test, unless stated in otherwise. There are tests in which a restart is not allowed.
   2.2. **Procedure:** In case a restart is allowed, the team may request the restart only before 50% of the time alloted to the test. The complete test is then restarted from the beginning (e.g., with entering the arena). The referees may rearrange the locations of objects/persons if necessary.
   2.3. **Time:** The time is neither restarted nor stopped. The team has 1 minute to restart the test (the same time to start the test); if the team is not able to do so in the allotted time, the test is called as finished by the TC.
   2.4. **Score:** The score of the second run (after the restart) counts. If it is lower than the score of the first run (before the restart), the average score of first and second run is taken.
   2.5. **Forced restart:** The referees and the monitoring TC member may force the team to do a restart:
   - if the robot is doing nothing or nothing reasonable for *one minute*, or
   - when the robot fails to understand a command for *five times*, or
   - after a minor collision

3.9. Bypassing features: CONTINUE rule

Because the show must go on

Having problems with certain particular ability should not disqualify a robot from showing up what it can do best, for demonstrating robots' abilities is important in RoboCup@Home.

To prevent this situation, when a robot is unable to perform a speech recognition or manipulation task, it may request human assistance and continue with the test; however, no points are

scored for solving the involved task. The Referee of the test determines the applicability of the CONTINUE rule and whether points are scored.

3.9.1. Bypassing Automatic Speech Recognition

Giving commands to the robot is essential in many tests. To foster natural human-robot interaction, speech has been chosen as the primary way to command a robot; but Automatic Speech Recognition (ASR) is not infallible.

Because active robots are preferred over robots that are passive due to failing ASR, teams are allowed to provide means to bypass ASR via an Alternative method for HRI (see Section 3.9.1).

Procedure

Automatic Speech Recognition is preferred and any command given to the robot will given by voice first.

1. **Default Operator:** The command for the robot is spoken out loud and clear by the human operator. This grants 100% of the available points for understanding the command. The *default operator* may repeat the command up to three times.
2. **Custom Operator:** When the robot renders unable to understand the default operator, the team leader can choose a *custom operator* can give the command *exactly as instructed by the referee*. Unless stated otherwise, only 75% of the points are granted. A *custom operator* may repeat the command up to three times.
3. **Alternative Input Method:** When the robot renders unable to understand the command given by a *custom operator*, it is allowed to use any alternative method or interface (see Section 3.9.1) previously approved by the TC during the Robot Inspection (see Section 4.4). No points are scored this way.

Alternative input methods for HRI

Alternative methods for HRI offer a way for a robot to start or complete a task. Any reasonable method may be used, with the following criteria:

- **Intuitive to use and self-explanatory:** a manual should not be needed. Teams are not allowed to explain how to interface with the robot.
- **Effortless use:** Must be as easy to use as uttering a command.
- **Is smart and preemptive:** The interface adapts to the user input, displaying only the options that make sense or that the robot can actually perform.
- Exploits the best of the device being used (eg. touch screen, display area, speakers, etc.)

Preferably, the alternative HRI must be also adapted to the user. Consider localization (with English as the default), but also potential users of service robots at their home. For example: elderly people and people with physical disabilities.

Award: The best alternative is awarded the Best Human-Robot Interface award (Section 1.7.2).

3.9.2. Bypassing Manipulation

Manipulating objects is a desirable feature for a domestic robot that also is required in many tests. However, due to design constrains, or even to malfunctioning a robot could fail a test when unable to grasp an object. To prevent this situation, robots that are aware of their limited manipulation capabilities can request human assistance during manipulation. When a human assists a robot in a manipulation task, no points are scored for manipulating them. However, the referee may grant proportional points in those cases when the task involves manipulation partially.

Procedure

Autonomous manipulation is desired, however, it is preferred for a robot to request human assistance over damaging itself, the furniture or the objects.

1. **Attempt autonomous manipulation:** Optional. The robot may try (but is not required) to manipulate the object by itself. Robots can request assistance after a failed attempt.
2. **State intention:** When the robot renders unable to manipulate an object, it must request for human assistance, clearly stating the nature of the assistance, such as opening a door, uncapping a bottle, grasping an object, etc.
3. **Closed-loop HRI:** When asking for assistance, the robot must be aware of the human's actions, like indicating which door to open, which object to take, or by guiding the human during the operation (eg. telling when to stop doing something).

   When grasping or moving objects, the robot needs to clearly specify (and, when possible, point out) the properties of the object to take or move (eg. specifying relative size, colour, shape, type, etc.), confirming that the human assistant has taken the correct object and, when required, also the exact placing location and transportation procedure.
4. **Thank for the help:** Robot must be polite and thank the human once the interaction has finished (e.g. once the door has been opened).

Remark: When using the CONTINUE rule to bypass autonomous manipulation, it is not possible to also use the CONTINUE rule to bypass Automated Speech Recognition.

3.10. Special penalties and bonuses

3.10.1. Penalty for not attending

1. **Automatic schedule:** All teams are automatically scheduled for all tests.
2. **Announcement:** If a team cannot participate in a test (for any reason), the team leader has to announce this to the OC at least *60 minutes* before the test slot begins.
3. **Penalties:** A team that is not present at the start position when their scheduled test starts, the team is not allowed to participate in the test anymore. If the team has not announced that it is not going to participate, it gets a penalty of *150 points*.

3.10.2. Extraordinary penalties

1. **Penalty for inoperative robots:** If a team starts a test, but it does not solve any of the partial tasks (and is obviously not trying to do so), a penalty of *50 points* is handed out. The decision is made by the referees and the monitoring TC member.
2. **Extra penalty for collision:** In case of major, (grossly) negligent collisions the *Technical Committee* (TC) may disqualify the team for a test (the team receives *0 points*), or for the entire competition.
3. **Not showing up as referee or jury member:** If a team does not provide a referee or jury member (being at the arena on time), the team receives a penalty of *150 points*, and will be remembered for qualification decisions in future competitions.
   Jury members missing a performance to evaluate are excluded from the jury, and the team is disqualified from the test (receives *0 points*).
4. **Modifying or altering standard platform robots:** If any unauthorized modification is found on a Standard Platform League robot, the responsible team will be immediately disqualified for the entire competition while also receiving a penalty of *150 points* in the overall score. This behavior will be remembered for qualification decisions in future competitions.

3.10.3. Bonus for outstanding performance

1. For every regular test in *Stage I* and *Stage II*, the @Home *Technical Committee* (TC) can decide to give an extra bonus for *outstanding performance* of up to 10% of the maximum test score.
2. This is to reward teams that do more than what is needed to solely score points in a test but show innovative and general approaches to enhance the scope of @Home.
3. If a team thinks that it deserves this bonus, it should announce (and briefly explain) this to the *Technical Committee* (TC) beforehand.
4. It is the decision of the *Technical Committee* (TC) if (and to which degree) the bonus score is granted.

3.11. General Instructions for Organizing Committee

Although there are instructions for the OC are specified per test, there are several aspects that the OC requires to carry out for competition in general:

During competition:

- Provide TC and referees with scoring sheets, pens, clipboards, stopwatches and other material relevant of carrying out the scoring.
- Post time schedules in the allotted spaces for the team's knowledge.

1h before each test:

- Organize referees.

Chapter 4

Setup and Preparation

Prior to the RoboCup@Home competition, all arriving teams will have the opportunity to setup their robots and prepare for the competition in a *Setup & Preparation* phase. This phase is scheduled to start on the first day of the competition, i.e., when the venue opens and the teams arrive. During the setup phase, teams can assemble and test their robots. On the last setup day, a *welcome reception* will be held. To foster the knowledge exchange between teams a conference-like *poster session* takes place during the reception. All teams have to get their robots inspected by members of the TC to be allowed to participate in the competition.

Regular tests are not conducted during setup & preparation. The competition starts with Stage I (Section Section 5).

Table 4.1.: Stage System and Schedule per League (distribution of tests and stages over days may vary)

Setup & Preparation	*Stage I*	*Stage II*	*Finals*
	advance → All teams that passed Inspection	*advance* → Best 10 (< 6) or best 50% (≥ 12)	*advance* → Best 2 teams

4.1. General Setup

Depending on the schedule, the *Setup & Preparation* phase lasts for one or two days.

1. **Start:** Setup & Preparation starts when the venue opens for the first time.
2. **Intention:** During Setup & Preparation, teams arrive, bring or receive their robots, and assemble and test them.
3. **Tables:** The local organization will setup and randomly assign team tables.
4. **Groups:** Depending on the number of teams, the *Organizing Committee* (OC) may form multiple groups of teams (usually two) for the first (and second stage). The OC will assign teams to groups and announce the assignment to the teams.
5. **Arena:** The arena is available to all teams during Setup & Preparation. The OC may schedule special test or mapping slots in which arena access is limited to one or more teams exclusively (all teams get slots). Note, however, that the arena may not yet be complete and that last works are conducted in the arena during the setup days.

6. **Objects:** The delegation of EC, TC, OC and local organizers will buy the objects (see Section Section 3.2.5). Note, however, that the objects may not be available at all times and not from the beginning of Setup & Preparation.

4.2. Welcome Reception

Traditionally –since Eindhoven 2013– the RoboCup@Home holds an own *welcome reception* in addition to the official opening ceremony. During the welcome reception, a *poster session* is held in which teams present their research foci and latest results (see Section Section 4.3).

1. **Time:** The welcome reception is held in the evening of the last setup day.
2. **Place:** The welcome reception takes place in the @Home arena and/or in the RoboCup@Home team area.
3. **Snacks & drinks:** During the welcome reception snacks and beverages (beers, sodas, etc.) are served.
4. **Organization:** It is the responsibility of the OC and the local organizers to organize the welcome reception & poster session including
   4.1. organizing poster stands (one per team) or alternative to present the posters,
   4.2. organizing the snacks and drinks,
   4.3. inviting officials, sponsors, local organization and the trustees of the RoboCup Federation to the event.
5. **Poster presentation:** During the welcome reception, the teams give a poster presentation on their research focus, recent results, and their scientific contribution. Both the poster and the teaser talk are evaluated by a jury (see 4.3).

4.3. Poster Teaser Session

Before the welcome reception & poster session, a *poster teaser session* is held. In this teaser session, each team can give a short presentation of their research and the poster being presented at the poster session.

4.3.1. Poster teaser session

1. **Presentation:** Each team has a maximum of three minutes to give a short presentation of their poster.
2. **Time:** The poster teaser session is to be held before the welcome reception & poster session (see Section Section 4.2).
3. **Place:** The poster session may be held in or around the arena, but should not interfere with the robot inspection (see Section Section 4.4).
4. **Evaluation:** The teaser presentation and the poster presentation are evaluated by a jury consisting of members of the other teams. Each team has to provide one person (preferably the team-leader) to follow and evaluate the entire poster teaser session and the poster session. Not providing a person results in no score for this team in the *Open Challenge*.

5. **Criteria:** For each of the following evaluation criteria, a maximum of 10 points is given per jury member:
   5.1. Novelty and scientific contribution
   5.2. Relevance for RoboCup@Home
   5.3. Presentation (Quality of poster, teaser talk and discussion during poster session)
6. **Score:** The points given by each jury member are scaled to obtain a maximum of 50 points. The total score for each team is the mean of the jury member scores. To neglect outliers, the N best and worst scores are left out:

$$score = \frac{\sum \text{team-leader-score}}{\text{number-of-teams} - (2N+1)}, N = \begin{cases} 1, & \text{number-of-teams} \geq 10 \\ 2, & \text{number-of-teams} < 10 \end{cases}$$

7. **Sheet collection:** Evaluation sheets are collected by the OC at a later time (announced beforehand by the OC), allowing teams to continue knowledge exchange during the first days of the competition (Stage I).
8. **OC Instructions:**
   - Prepare and distribute evaluation sheets (before the poster teaser session.)
   - Collect evaluation sheets.
   - Organize and manage the poster teaser presentations and the poster session.

4.4. Robot Inspection

Safety is the most important issue when interacting with humans and operating in the same physical workspace. Because of that all participating robots are inspected before participating in RoboCup@Home. Every team needs to get its robot(s) inspected and approved for participation.

1. **Procedure:** The *robot inspection* is conducted like a regular test, i.e., starts with the opening of the door (see Section Section 3.8.8). One team after another (and one robot after another) has to enter the arena through a designated entrance door, move to the *examination point*, and leave the arena through the designated exit door. In between entering and leaving the robot is inspected.
2. **Inspectors:** The robots are inspected by the *Technical Committee* (TC).
3. **Checked aspects:** It is checked if the robots comply with the rules (see Section Section 3.3), checking in particular:
   - emergency button(s)
   - collision avoidance (a TC member steps in front of the robot)
   - voice of the robot (it must be loud and clear)
   - custom containers (bowl, tray, etc.)
   - external devices (including wireless network), if any
   - Alternative Human-Robot interfaces(Section 3.9.1).
   - ***Standard Platform robots***
     - Neat appearance
     - No modifications have been made
   - ***Open Platform robots***

  - robot speed and dimension
  - start button (if the team is going to require it)
  - robot speaker system (plug for RF Transmission)
  - other safety issues (duct tape, hanging cables, sharp edges etc.)

4. **Re-inspection:** If the robot is not approved in the inspection, it is the responsibility of the team to get the approval (later). Robots are not allowed to participate in any test before passing the inspection by the TC.
5. **Time limit:** The robot inspection is interrupted after three minutes (per robot). When told to so by the TC (in case of time interrupt or failure), the team has to move the robot out of the arena through the designated exit door.
6. **Appearance Evaluation:** In addition to the inspection, the TC evaluates the appearance of the robots. Robots are expected to look nice (no duct tape, no cables hanging loose etc.). In case of objection, the TC may penalize the team with a penalty of maximum 50 points.
7. **Accompanying team member:** Each robot is accompanied by only one team member (team leader is advised).
8. **OC instructions (at least 2h before the Robot Inspection):**
   - Announce the entry and exit doors.
   - Announce the location of the *examination point* into the arena.
   - Specify and announce where and when the poster teaser and the poster presentation session take place.
   - Prepare and distribute poster session evaluation sheets.

Chapter 5

Tests in Stage I

*Stage I comprehends five **ability tests** and an **integration test** along with an open demonstration for the audience. Each ability test is designed to evaluate the average performance of the robot in one particular skill, providing data for benchmarking. Meanwhile, the integration test has been designed to evaluate how this abilities work together while solving a common task.*

The total score for ability and integration tests is the average of the best two performances out of preferably three performances (given the time constraints of a competition). The point of this is the both elimate good and bad luck for the robots/teams and to get a more objective view of the performance, not to give teams time to tweak the robot between test performances.

Following and Guiding (demonstration for the audience) goes out of the arena and into the venue between the audience.

Scheduling

For maximal efficiency, teams will be scheduled interleaved: Team A does an attempt while team B sets up their robot. When A is done, it moves out the way for team B, then B attempts while A sets up the robot again etc.

The preparing team should prepare their robot close to the place of the test, but not interfere with the performing robot. Prepared robots must wait at this preparation location until commanded to start the test. When commanded to start, the robot must move automatically beyond this point.

Robot should be ready to start the next attempt to the same test as fast as possible: when the performing robot is done with a attempt, the next robot must be ready to go with the start of a button or a voice command.

5.1. Cocktail Party [SSPL only]

The robot has to learn and recognize previously unknown people, and fetch orders.

5.1.1. Focus

This test focuses on human detection and recognition, safe navigation and human-robot interaction with unknown people.

5.1.2. Setup

- **Party room**: any (large) room inside the apartment when normally a party would be held.
- **Guests:** At least five people are distributed in a predefined "party room" either sitting or standing, some of them forming groups of 2 or 3 people, from which at least one is sitting. Three of the guests have drink orders assigned by the referees. The sitting person always has an assigned drink.
- **Bar:** The bar is any flat surface where objects can be placed, in a room other than the "party room". All available beverages are on top of the bar for the robot can see them.
- **Barman:** The Barman bay be standing either behind the bar or next to it, depending on the arena setup.

5.1.3. Task

1. **Entering:** The robot enters the arena and navigates to the party room and waits for being called.
2. **Getting called:** The guests call the robot simultaneously, either rising an arm, waving, or shouting. The robot has to approach one of them. The calling person introduces themself by name before giving the order of a drink. The robot leads the dialogue to learn the person and retrieve their drink order.

   The robot can decide to skip the detection of the calling and ask one person to walk in front of it. In this case, the referees determine the person to approach the robot.
3. **Taking the order:** After the robot has fetched the order of the first guest, it can either fetch more orders (i.e. find next calling guest or looking for the sitting one) or proceed to place the order. In the first case, the robot searches for the remaining calling people. During the search process, the robot is allowed to either ask people to call for it again, or to ask people to come to it and to give a new order. In both cases the robot may call into the room.
4. **Sitting person:** At least one person is sitting and minding their own business (i.e. not looking directly to the robot). The robot must locate that person and ask if the person wants something to drink. The robot must also ask for the person's name and memorize them (i.e. execute a learning procedure of the name and the person's features).

   Remark: At least one sitting person has an order to place. No sitting person will not attend robot's call.

5. **Placing the orders:** The robot has to navigate to the *Bar*, a designated location in another room where drinks are served. The robot must repeat each order to the *Barman*, clearly stating:
   5.1. The person's name,
   5.2. The person's chosen drink,
   5.3. A description of unique characteristics of that person that allow the *Barman* to find them (e.g. gender, hair colour, how is dressed, etc).

   While the robot places the orders, the people in the "party room" may change their places within the party room (on request of the referees).
6. **Missing beverage:** One of the ordered drinks is not available, therefore, missing from the bar. The robot should realize this inconvenience and tell the *Barman*, providing a list of 3 alternatives considering the other drinks it needs to deliver. If the robot can't detect which drink is missing, the *Barman* will clearly state which of the beverages is not available and provide a list of 3 alternatives.
7. **Correcting an order:** The robot should navigate back to the "party room", find the person whose drink is missing and provide the alternatives for they to choose.

   If the robot comes to the place the person ordered and the person is not there, it can call that person loud, the person should respond (either sound or waving hand) and the robot must go to that place (check the person identity).
8. **Placing the corrected order:** The robot has to navigate to the *Bar* and inform the change on the guest's order. This time only the guest's name and drink can be provided.

5.1.4. Additional rules and remarks

1. **Repeating names:** The robot may ask to repeat the name if it has not understood it.
2. **Misunderstood names:** If the robot misunderstands the name, the understood (wrong) name is used in the remainder of this test.
3. **Misunderstood order:** If the robot does not understand the order, it can continue with an own assignment of drinks to people or with a wrong, misunderstood assignment.
4. **Approaching non-calling people:** If the robot approaches a person that is not calling and asks for an order, the person indicates that they does not want to order anything. No points can be scored for understanding names or orders, or for grasping or delivery for a non-calling person.
5. **Guest description:** The guest's description must be unique inside the scenario. For instance, it make no sense to state that a person is wearing a red T-shirt if two people are wearing them. In the same sense, stating that the ordering guest is *tall* can lead to confusion, but stating that is the *tallest* does not.
6. **Changing places:** After giving the order (when the robot is not in the party room), the referees may re-arrange the people including their body posture. That is, a sitting person may change to a standing posture and vice versa.
7. **Positions and orientations:** All people roughly stay where they are (if not asked to move by the referees), but they are allowed to move in certain limits (e.g. turn around, make a step aside). They do not need to look at the robot, but are requested to do so, when instructed by the robot.

8. **Empty arena:** During the test, only the robot, the guest, and the Barman are in the arena. The door opener, the referees and other personnel that is not assigned as test people will be outside the scenario.
9. **Calling instruction:** The team needs to specify before the test which ways of getting the attention of the robot are allowed. This can be waving, calling or both of them. The robot can also decide to skip this part, by asking for people to get close to it.

5.1.5. Referee instructions

The referees need to

- select 5 people and their names from the list of person names (see Section 3.2.8),
- arrange (and re-arrange) people in the party room,
- select the person (barman) who will serve the drinks,
- select the ordering 3 people and the orders to give,
- in case the robot skips the calling detection, select the ordering person to approach the robot,
- write down the understood names and drinks during an order and update the order accordingly.

5.1.6. OC instructions

2h before test:

- Specify and announce the rooms where the test takes place.
- Specify and announce the location where the drinks are served.

5.1.7. Score sheet

The maximum time for this test is 5 minutes.

Action	Score
Taking the orders	
Detecting calling person	*2 ×* *15*
Finding sitting & distracted person	*30*
Understanding and repeating the correct person's name	*3 ×* *5*
Understanding and repeating the correct drink's name	*3 ×* *5*
Placing orders	
Repeat the correct name & drink to the Barman	*3 ×* *5*
Provide an accurate description of the guest to the Barman	*3 ×* *30*
Missing beverage	
Realize the missing drink	*20*
Provide 3 available alternatives to the Barman	*20*
Understanding and repeating the alternatives to the Barman	*5*
Correcting the order	
Find the guest without calling them	*20*
Find the guest by calling them	*10*
Repeat the correct list of alternate drinks to the guest	*5*
Understanding and repeating the corrected order	*5*
Place the corrected order	*5*
Penalties	
Talk to something that is not a human	*-1 ×* *20*
Special penalties & standard bonuses	
Contributing with recorded data ($\frac{\sum gathered\ points}{max\ points}\times$) (see sec. 3.4)	*10*
Not attending (see sec. 3.10.1)	*-50*
Outstanding performance (see sec. 3.10.3)	*27*
Total score (excluding penalties and bonuses)	*270*

5.2. General Purpose Service Robot

This test evaluates the abilities of the robot that are required throughout the set of tests in stage I of this and previous years' RuleBooks. In this test the robot has to solve multiple tasks upon request. That is, the test is not incorporated into a (predefined) story and there is neither a predefined order of tasks nor a predefined set of actions. The actions that are to be carried out by the robot are chosen randomly by the referees from a larger set of actions. These actions are organized in three categories with different complexity. Scoring thereby depends on the complexity class.

5.2.1. Focus

This test particularly focuses on the following aspects:

- No predefined order of actions to carry out (to get away from state machine-like behavior programming).
- Increased complexity in speech recognition.
- Environmental (high-level) reasoning.
- Efficient and fast task execution (speed).

5.2.2. Task

1. **Entering and command retrieval:** The robot enters the arena and drives to a designated position where it has to wait for further commands.
2. **Command generation:** A command is generated randomly, depending on the command category chosen by the team (see below).

3. **Command categories:** The team may choose from the following three categories:
   3.1. **Category I:** Tasks with a low difficulty degree.
   3.2. **Category II:** Tasks with a moderate difficulty degree.
   3.3. **Category III:** Tasks with a high difficulty degree or with incomplete/erroneous information.
4. **Task assignment:** The robot is given the command by the operator and may directly start to work on the task assignment.
5. **Returning to the operator:** After accomplishing the assigned task, the robot has to move back to the operator to retrieve the next command (i.e., go back to 1. without the need of re-entering the arena). The robot can work on at most three commands. After the third command, it has to leave the arena.
6. **Exiting the arena:** After accomplishing the assigned task, the robot has to leave the arena.
   The robot must prove it has understood the given command by repeating it (Please see the remarks about this in section 5.2.3).

5.2.3. Additional rules and remarks

1. **Referees:** Since the score system in this test involves a subjective evaluation of the robot's behavior, the referees are EC/TC members.

2. **Category selection:** For every of the three commands given to the robot, the team chooses the desired command category.
3. **Operator:**
   - The person operating the robot is one of the referees (default operator).
   - If the robot appears to consistently not be able to understand the operator, the referees ask the team to use a custom operator or bypassing speech recognition (Section 3.9.1).
4. **Retrieving the command:** The robot must show it has understood the given command by repeating the command (i.e. stating all the required information to accomplish the task.).
5. **Incremental scoring:** Scoring depends on the category chosen by the team leader and the previous successfully accomplished command. Thereby, scoring for a second and third command depends on how well the robot solved (not understood) a first and second command respectively. Referees determine how well the command was accomplished and its impact on the incremental scoring of subsequent commands.

5.2.4. Referee and OC instructions

2h before test:

- Specify and announce the entrance and exit door

5.2.5. Score sheet

The maximum time for this test is 10 minutes.

Action	Score
Getting instructions	
Understanding the command on the 1^{st} attempt	*3* × *10*
Understanding the command on the 1^{st} attempt (Custom Operator)	*3* × *5*
Understanding the command at a later attempt	*3* × *1*
First Command Successfully Solved	
Command Category I	*10*
Command Category II	*20*
Command Category III	*30*
Second Command Successfully Solved	
Command Category I	*20*
Command Category II	*40*
Command Category III	*60*
Third Command Successfully Solved	
Command Category I	*40*
Command Category II	*80*
Command Category III	*120*
Leave the arena	
Leave the arena after successfully accomplishing a command	*10*
Special penalties & standard bonuses	
Contributing with recorded data ($\frac{\sum gathered\ points}{max\ points}$×) (see sec. 3.4)	*10*
Not attending (see sec. 3.10.1)	*-50*
Outstanding performance (see sec. 3.10.3)	*25*
Total score (excluding penalties and bonuses)	*250*

5.3. Help-me-carry

The robot's owner went shopping for groceries and needs help carrying the groceries from the car into the home.

5.3.1. Goal

The robot must help bringing some objects into the arena from outside.

5.3.2. Focus

This test focuses on safe, robust navigation, people following and navigation in unknown environments.

DSPL & OPL Test focuses also in Object Detection and Manipulation.
SSPL Test focuses also in People Detection and Human-Robot Interaction.

5.3.3. Setup

The operator (the robot's owner) has a set of bags (and possibly other objects) that need to be carried from a place outside the arena back inside.

1. **Location:** One of the arenas (apartment) and its surroundings. The apartment is in its normal state. Part of the test is performed outside the arena in a public space.
2. **Start:** The robot starts waiting inside the arena.
3. **Car:** The car is any landmark chosen (but *not* announced) beforehand outside the arena. Several bags (see Section 3.2.5) with groceries are located where the car is parked.
4. **Doors:** All doors in the apartment are initially open.
5. **Operator:** A "professional" operator is selected by the TC to act as the operator of the robot.
6. **Uncontrolled environment:** There are no restrictions on other people walking by or standing around throughout the complete task.

5.3.4. Task

1. **Start:** The robot starts at a designated starting position in the arena, and waits for the *professional* operator. The operator steps in front of the robot and tells it to follow (e.g. by saying "follow me"). The team is *not* allowed to instruct the operator.
2. **Memorizing the operator:** The robot has to memorize the operator. During this phase, the robot may instruct the operator to follow a certain setup procedure.
3. **Following the operator:** When the robot signals that it is ready to start, the operator starts walking –in a natural way– towards the car. Upon arrival, the operator will indicate the robot when they have reached their destination as instructed by the robot (e.g. by saying "here is the car" or "stop following me").
4. [DSPL & OPL] **Bring the groceries in**
   The robot is asked to deliver a bag with groceries to a specific location (e.g. "Take this bag to the kitchen table").

4.1. **Bag pick-up:** The robots gets the bag. For this there are several options to achieve this: **a)** Human puts bag in robot's hand, **b)** robot picks up bag on floor, **c)** Robot takes bag from operator's hand

4.2. **Bag delivery:** The robot delivers the bag to the instructed destination. It may place the bag on the floor or onto the placement location.

4.3. **Asking for help:** Close to the delivery location is another person. The robot must face at them and kindly ask them to help carrying groceries into the house.

4. [SSPL only] **Look for help**
The robot is asked to find a person in a given room and ask them to assist carrying the groceries (e.g. "Look for Louise in the Kitchen and ask her to help us").

4.1. **Entering the house:** While on its way back to the house, the robot deals with different obstacles along it's path.

1st section While going back to the house, a person crosses robot's path.

2nd section While going back, a person steps in front of the robot and asks it for the time.

4.2. **Find a person:** After reaching the designated room, the robot needs to find a person (there is only one person in the room, the name is meaningless).

5. **Memorizing the *new* operator:** The robot has to memorize the operator that will help. During this phase, the robot may instruct the operator to follow a certain setup procedure.
6. **Guiding the operator:** When the robot signals that it is ready to start guiding, the robot guiding the operator to the car. The robot must clearly announce when the destination (the car) is reached.

DSPL & OPL **Closed door:** Along it's path to the car, the robot will find a closed door (most likely the entrance to the house) that will need to be opened to reach the destination.

SSPL only **Distracted operator:** After leaving the house, the operator is distracted by another person. The robot must re-gain the operator's attention, remind the task, and continue guiding the operator's to the car.

5.3.5. Obstacles

The robot will encounter some obstacles while navigating and the robot must deal and avoid or otherwise deal with the obstacle. The possible obstacles are:

- **3D Object:** A hard to see object that requires more than a laser scanner to be detected such as a bar table (wider at its top than on its bottom), rolling chair, lamp, etc.
- **Small object:** Small object. For example, someone has dropped a piece of fruit (like an apple or mandarin) while carrying the groceries inside.
- [DSPL and OPL] **Movable Object:** An object blocking the robot's path which the robot can manipulate or push away (such a rolling chair). When interacting with movable objects, the robot must state clearly that the object will be pushed or moved away.

- [SSPL Only] ***Smart* obstacle:** A person blocking the robot's path to whom the robot may speak to and kindly ask to move away. When interacting with people, the robot must look at the person and make clear it is speaking with them.

5.3.6. Additional rules and remarks

Figure 5.1.: Paper bag

Figure 5.2.: Car

1. **Asking for passage:** The robot is allowed to (gently) ask individual people to step aside, but it is not allowed to blindly shout at groups of people.
2. **Bag handles:** The handles of the bag are always clear and standing up. See Figure 3.2a in Section 3.2.5 for bag description. [1]
3. **Bag pick-up:** If the robot can't handover the bag from the operator (i.e. take it from the operator's hand) it may pick another bag from the surroundings. Additional bags might be either on the floor or on a table. It is expected the robot to actively try to grasp the bag from the operator's hand, and not passively waiting for the bag to be hanged on it. Shall the robot wait for the operator to hang the bag themself, the robot must clearly state it has detected the bag has been placed.
4. **Calling the operator back:** During the following phase, when the robot has lost the operator, it may call the operator back once.
5. **Disturbances from outside:** If a person from the audience (severely) interferes with the robot in a way that makes it impossible to solve the task, the team may repeat the test immediately.
6. **Groceries:** Any kind of objects can be found lying around the location designated as the *Car*, such as boxes, sacs, plastic bags, crates, and the groceries itself to give realism to the test. Regardless what objects are present, the robot shall carry an **official shopping bag** as described below and in Section 3.2.5.
7. **Instruction:** The robot interacts with the operator, not the team.
8. **Natural walking:** The operator has to walk "naturally", i.e., move forward facing forward. If not mentioned otherwise, the operator is not allowed to walk back, stand still, signal the robot or follow some re-calibration procedure.
9. **Obstacle avoidance:** The robot will encounter several obstacles it must evade on its path between the car and the target destination. The robot might be allowed to collide (but not crush) with the small object without the test to be immediately stop. For example, it is allowed to push aside a block of wood, but it won't be allowed to even touch a mandarin or soda can.
10. **Opening door:** If unable to open the door, the robot may ask the person being guided to open it (no points are scored).

5.3.7. Data recording

Please record the following data (See Section 3.4):

[1] This may change in the future. Then, a soft handle may be used which folds down

- Maps
- Plans

5.3.8. Referee instructions

The referee needs to

- Distribute some objects over the shopping bags.
- Designate a few "car parking locations" from which the objects must be carried.

5.3.9. OC instructions

During setup days

- Make bags available.

2 hours before the test

- Announce the location in which robots will start.
- Get and instruct volunteers for the test.

5.3.10. Score sheet

The maximum time for this test is 5 minutes.

Action	Score
Following Phase	
Follow operator outside the arena	*10*
Follow operator to the car	*15*
Understand the destination	*5*
Bag pick-up (OPL & DSPL only)	
Put up hand, closing it after waiting time elapses	
Put up hand, closing it right after the bag is inserted	*2*
Pick up the bag from the floor	*5*
Take bag from operator's hand (natural handover)	*20*
DSPL & OPL Tasks	
Re-enter the arena	*10*
Deliver the bag at the specified location	*5*
Find the person at the specified location	*10*
Open door without help	*30*
Guide operator outside the arena	*10*
Guide operator to the car	*15*
SSPL only Tasks	
Tell the time to the stranger	*10*
Re-enter the arena	*30*
Find the person at the specified room	*20*
Guide operator outside the arena	*10*
Guide operator to the car	*30*
Obstacle avoidance	
Avoiding small (box-sized) object	*20*
Avoiding 3D (hard-to-see) object	*20*
[SSPL] Asking a person to step aside (*smart* obstacle)	*30*
[DSPL & OPL] Moving away movable object	*30*
Special penalties & standard bonuses	
Contributing with recorded data ($\frac{\sum gathered\ points}{max\ points}\times$) (see sec. 3.4)	*10*
Not attending (see sec. 3.10.1)	*-50*
Outstanding performance (see sec. 3.10.3)	*20*
Total score (excluding penalties and bonuses)	*200*

5.4. Speech and Person Recognition

The robot has to identify unknown people and answer questions about them and the environment.

5.4.1. Focus

This test focuses on human detection, sound localization, speech recognition, and robot interaction with unknown people.

5.4.2. Setup

1. **Location:** One room of the arena is used for this test[2].
2. **Crowd:** There is a crowd of 5 to 10 people in the designated room. People may be standing, sitting, lying, and in any pose.
3. **Doors:** All doors of the apartment are open, except for the entry door.

5.4.3. Task

1. **Start:** The robot starts at a designated starting position and announces it wants *to play riddles*.
2. **Waiting and turn:** After stating that it wants *to play a riddle game*, the robot waits for 10 seconds while a crowd is merged on it's back. When the time elapses, the robot must turn around (about 180°) and find the crowd.
3. **Requesting an operator:** After turning around, the robot must state the size of the crowd (including male and female count[3]) and request for an operator (e.g. *who want to play riddles with me?*). The crowd will move and surround the robot, letting the operator to stand in front of the robot.
4. **The riddle game:** Standing in front of the robot, the operator will ask 5 questions. The robot must answer the question without asking confirmation. Questions will only be asked only once; no repetitions are allowed.
5. [DSPL only] **Blind man's bluff game: Crowd line-up.** The crowd will reposition, lining up in front of the robot. A random person from the crowd standing in front of the robot will ask a question. The robot may

   - Turn towards the person who asked the question and answer the question
   - Directly answer the question without turning
   - Turn towards the person and ask them to repeat the question

   This process is repeated with 10 (possibly) different people. The game will end when the 10th question has been made, following a similar distribution of questions as in the riddle game. The robot must answer the question without asking confirmation. Questions may be repeated once.

[2] This test may also be held outside the arena

[3] It is possible to state the number of people whose gender couldn't be determined by the robot, therefore stating correctly the size of the crowd and, possibly, one of the gender groups.

5. [OPL & SSPL] **Blind man's bluff game: Circling Crowd.** The crowd will reposition, making a circle around the robot. A random person from the crowd surrounding the robot will ask a question. The robot may
   - Turn towards the person who asked the question and answer the question
   - Directly answer the question without turning
   - Turn towards the person and ask them to repeat the question

   This process is repeated with 5 (possibly) different people. The game will end when the 5th question has been made, following the same distribution of questions as in the riddle game. The robot must answer the question without asking confirmation. Questions may be repeated once.
6. **Leave** The robot must leave the arena/test area after all questions have been asked or when instructed to do so.

5.4.4. Additional rules and remarks

1. **Bypassing ASR:** Bypassing Automated Speech Recognition via the CONTINUE rule (Section Section 3.9.1) is not allowed during this test.
2. **Asked questions:** The distribution of questions to be randomly asked is a follows:
   - One is a predefined question
   - Between one and two are about the arena and its status
   - Between one and two are about the crowd
   - Between one and two are about the list of official objects

   Question examples see Appendix Section A.
3. **Distance to the robot:** The distance between each person and the robot must be between 0.75 and 1.0 meters away from the robot position (See Figure 5.3). In the *riddle game* the operator shall be between -60° and 60° from the robot's center (front range).
4. **Precise turning:** When the robot finishes turning toward an operator, it must be clear that the robot is facing the person who made the question.
5. **Question repetition:** In the *blind man's bluff game*, if the robot asks for repetition, it should be done clear and loud, and after the robot has ended turning.
6. **Question timeout:** If the robot does not answer within 10 seconds, the question is considered as *missed*, and referee will proceed with the next one.
7. **Standing still operators** Operators are not allowed to move to or turn towards the robot or shout to the robot.
8. **Water-clear answers:** If the referee is unable to hear or understand the robot's answer, the question is considered as *incorrect*. Single-word and short answers should be avoided

5.4.5. Data recording

Please record the following data (See Section 3.4):

- Audio
- Commands
- Images

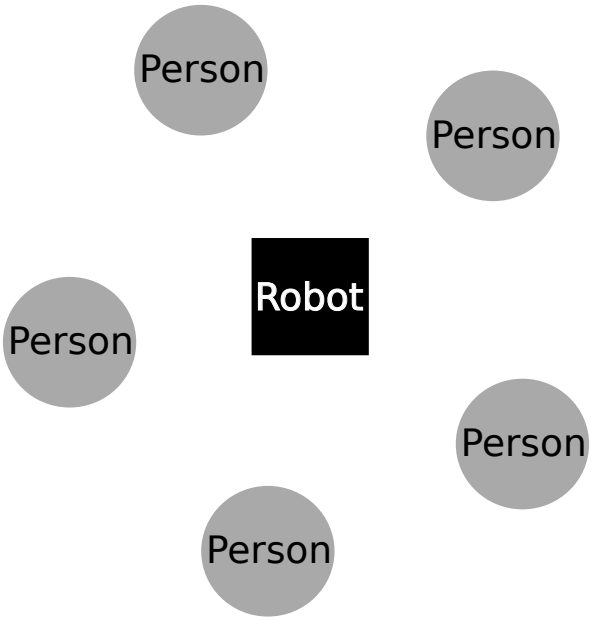

Figure 5.3.: Speech recognition test: person setup around the robot for 2nd part.

5.4.6. Referee instructions

The referee needs to

- avoid shouting to the robot
- avoid getting closer to the robot (or even move)
- speak to the robot loud and clear with plain standard English
- avoid repeating questions for the same robot
- distribute the questions among the volunteers

5.4.7. OC instructions

1 day before the test

- Provide the set of predefined questions

2 hours before the test

- Announce the placement of the robots
- choose the volunteers for the second part of the test, and clearly explain the procedure to them.
- When the test is held outside the arena, announce the (way)point through which the robot shall leave

5.4.8. Score sheet

The maximum time for this test is 5 minutes.

Action	Score
Crowd	
State crowd's size	*5*
State crowd's male/female count	*10*
Riddle game	
Understanding question	*5* × *5*
Correctly answered a question	*5* × *5*
Answering all 5 riddle game question	*5*
[DSPL only] Blind man's bluff game	
Understanding question on the first attempt	*10* × *5*
Understanding question on the second attempt	*10* × *2*
Correctly answered a question	*10* × *2*
Turned towards person asking the question	*10* × *5*
Answering all 10 blind man's bluff questions	*10*
[OPL & SSPL] Blind man's bluff game	
Understanding question on the first attempt	*5* × *10*
Understanding question on the second attempt	*5* × *5*
Correctly answered a question	*5* × *5*
Turned towards person asking the question	*5* × *10*
Answering all 5 blind man's bluff questions	*5*
Special penalties & standard bonuses	
Contributing with recorded data ($\frac{\sum gathered\ points}{max\ points}\times$) (see sec. 3.4)	*10*
Not attending (see sec. 3.10.1)	*-50*
Outstanding performance (see sec. 3.10.3)	*20*
Total score (excluding penalties and bonuses)	*200*

5.5. Storing Groceries [DSPL & OPL]

The robot helps by storing newly bought groceries in the cupboard next to the objects of the same kind that are already there; for instance by placing fresh apples where the other apples are.

5.5.1. Goal

The robot has to correctly identify and manipulate objects at different heights, grouping them by category and likelihood.

5.5.2. Focus

This test focuses on the detection and recognition of objects and their features, as well as object manipulation.

5.5.3. Setup

1. **Location:** One of the bookcases or cupboards in the apartment is used for this test, one where a table is near or can be put.
2. **Start position:** The robot will start between the cupboard and the table in a random orientation, but facing towards the Cupboard. .
3. **Cupboard:** The cupboard has 5 shelves between 0.30m and 1.80m from the ground and contains several objects (See 3.2.5).
   - **Door:** The cupboard has a single door, which is closed initially. This door encloses some of the objects, covering up to one half of the cupboard (e.g. the left or bottom half), as indicated by the hatched area in the image.
4. **Table:** A table near to the Cupboard has 10 objects (See 3.2.5). If not all fit the on the table, they will be added during the test. The maximum distance between the Table and the Cupboard is 2m.
5. **Objects:** Objects on the Cupboard and on the Table can be known, alike, or unknown. Also, there will be more than one object in each shelf.

Figure 5.4.: Shelf

5.5.4. Task

1. **Opening door:** The robot starts opening the Cupboard's door. If the robot is unable to open the door, it may ask the Referee to do it instead.
2. **Cupboard inspection:** The robot inspects the cupboard locating and categorizing existing groceries.
3. **Finding the table:** The turns around and locates the table.

4. **Table inspection:** The robot approaches the table starts analyzing the newly bought groceries (i.e. objects).
5. **Moving objects:** The robot chooses which object to move first from the Table to the Cupboard, allocating similar objects all together.
   - Objects of the same type (i.e. identical known objects or akin alike objects) must be placed one next to the other.
   - If the Cupboard has no object of the same type, then objects must be grouped by category (e.g. drinks with drinks, snacks with snacks, etc)
   - If the Cupboard has no similar object, the robot must clearly state its decision on how to solve the problem. For instance, the robot can define a place for the newly found Category (e.g. Food was found but there is no other food in the cupboard), or group all new objects together (e.g. placing all Unknown objects together).

   Note: Either before or after grasping an object the robot may announce the name of the object found.
6. **Repeat:** This repeats until the time is up or all groceries are stored.

5.5.5. Additional rules and remarks

1. **Bypassing Manipulation:** Bypassing object manipulation via the CONTINUE rule (Section Section 3.9.1) is not allowed during this test.
2. **No setup:** There is no setup time.
3. **Startup:** The robot can be started with a simple voice command or via a start button (Section Section 3.8.8).
4. **Single try:** The robot must be able to start from the first attempt. There is no restart for this test. If the robot is unable to start it must be removed immediately.
5. **Collisions:** Slightly touching the the cupboard is tolerated (but not advised). Crushing objects or any other form of a major collision terminates the test immediately (Section Section 3.8.1).
6. **Recognition report:** Robots must create a PDF report file including
   6.1. The name of the team.
   6.2. The try number (to identify between runs).
   6.3. The date and time.
   6.4. Picture of the cupboard in its initial state with bounding boxes enclosing each group and a human-readable labels to identify them.
   6.5. The list of moved objects; each one with a picture showing the object inside a bounding box with a label stating the object's name, category, and any other relevant information used to categorize the object.
   6.6. Picture of the cupboard in its final state with bounding boxes enclosing each group and a human-readable labels to identify them.

   The report file must be stored on a USB-stick on the robot, which will be collected by the TC immediately after the test. The PDF file must be named with the following format: `TeamName_RunNumber.pdf`

   Remark: It must be unmistakable which label belongs to which object. Objects must

also be easily recognizable in the report by a human (TC) so that it can be scored.

Remark: False positives in the report (labeling an object which is not an object but e.g. the edge of the shelf) are penalized.
Unknown objects: A significant amount of objects are unknown objects. A correct label for these may be constituted by:

- Simply labeling those as "Unknown" as opposed to wrongly applying a label from the known or alike objects
- Labeling pairs of unknown objects of the same class with the same label (which may be e.g. "type_X" for one pair and "relevant-feature_Y" for another).
- Labeling unknown objects with a new, sensible label for objects.

7. **Clear area:** The robot may assume that the direct vicinity of the cupboard and table are clear, and that the robot can move slightly backwards for its task.

5.5.6. Data recording

Please record the following data (See Section 3.4):

- Images
- Plans

5.5.7. OC instructions

2 hours before the test

- Announce the startup location for robots.

5.5.8. Referee instructions

The referee needs to

- Place the objects in the cupboard and a few of the same class on the table. New items can be placed when there is room or the robot asks for more objects.
- Close the door of the cupboard.
- Put objects on the table and the corresponding objects in the cupboard: 3 known objects, 2 alike and 5 unknown objects.

5.5.9. Score sheet

The maximum time for this test is 1+2+2 minutes. The first minute is for the robot to open the Cupboard's door on its own. If the robot is not able to open the door within that minute, it will be opened by the referee. In case the robot opens the door within the minute, the robot has a small time advantage. Then, the robot has 2 minutes to recognize objects and manipulate items. If an item is manipulated within that time, 2 more minutes are added to the test time. If not, the test ends.

Action	**Score**
Opening the door	
Opening the door without human help	*20*
Moving objects	
Successfully grasping an object (5 cm for more than 10 seconds)	*5 × 10*
Successfully placing an object near to another of the same class	*5 × 10*
Successfully placing an object anywhere else	*5 × 5*
Recognizing known or alike objects	
Every correctly recognized known or alike object in the report file	*10 × 5*
Recognizing unknown objects	
Correctly label unknown object as "Unknown"	*10 × 5*
Label a *pair* of unknown objects with the same label (e.g label both papayas both as "class A")	*5 × 20*
Label unknown object as correct category (e.g. label a papaya as fruit)	*10 × 15*
Label unknown object as correct class (e.g. label a papaya as papaya)	*10 × 15*
Incorrect recognitions	
False positive label	*10 × -5*
Special penalties & standard bonuses	
Contributing with recorded data ($\frac{\sum gathered\ points}{max\ points}\times$) (see sec. 3.4)	*10*
Not attending (see sec. 3.10.1)	*-50*
Outstanding performance (see sec. 3.10.3)	*32*
Total score (excluding penalties and bonuses)	*320*

Chapter 6

Tests in Stage II

All ability and integration tests in Stage II are performed only once. Some tests have optional tasks that grant additional points when performed correctly, clean and fast. The Technical Committee (TC) must be informed if a team is planning to perform any of the optional tasks. Unless explicitly stated otherwise, no additional time is given while performing optional tasks.

In the Open Challenge the robot must be able to show to the Technical Committee (TC) the achievements on the main research line of its own team. This test grants up to 250 points.

Robot & team cooperation

We encourage robots and teams to work together when performing tests. For scoring, points are awarded per subtask. The robot (and thus team) performing the subtask gets the points. For example, in the Restaurant test, if one robot of team A can take the order and another robot of team B delivers the order, then the points for taking the order go to team A, while the points for delivering go to team B. Of course, team A & B can both perform the test in their own turn.

6.1. Enhanced Endurance General Purpose Service Robot

This test evaluates the abilities of the robot that are required throughout the set of tests in stage II of this and previous years' RuleBooks. In this test the robot has to solve multiple tasks upon request over an extended period of time (30-45 minutes). That is, the test is not incorporated into a (predefined) story and there is neither a predefined order of tasks nor a predefined set of actions. The actions that are to be carried out by the robot are chosen randomly by the referees from a larger set of actions. These actions are organized in several categories targeting an special ability. Scoring depends on the abilities shown.

6.1.1. Focus

This test particularly focuses on the following aspects:

- No predefined order of actions to carry out (to get away from state machine-like behavior programming).
- Increased complexity in speech recognition.
- Environmental (high-level) reasoning.
- Robust long-term operation.

6.1.2. Task

1. **Entering and command retrieval:** The robot enters the arena and drives to a designated position where it has to wait for further commands.

2. **Command generation:** A command is generated randomly, depending on the command category chosen by the team (see below).

   2.1. **Category I: Advanced Manipulation.** The task requires handling objects into small or narrow spaces, manipulate tools, buttons, panels, and doors; two-handed manipulation, or eye-hand coordination.
   2.2. **Category II: Advanced Object Recognition.** The task requires describing unknown objects, recognize objects from description, identify occluded objects and from the distance.
   2.3. **Category III: Navigation & People Tracking.** The task involves following or guiding people in crowded environments or through narrow spaces. The navigation may take place either inside or outside the arena.
   2.4. **Category IV: People & Activity Recognition.** The task requires memorizing a person's features, describing unknown people, recognize people from description, and being able to find people hiding or from the distance.
   2.5. **Category V: Incomplete Information.** The robot gets a command that does not include all the information necessary to accomplish the task.
   2.6. **Category VI: Erroneous information.** The command contains erroneous information. The robot should be able to realize what went wrong and, when to carry on an alternative solution, it must go back to the operator and clearly state why it wasn't able to accomplish the task.

2.7. **Category VII: Memory and Environmental Reasoning.** The command requires remembering previously executed tasks. The robot should be able to realize previously performed changes to the environment and, when unable to solve the task, it must go back to the operator and clearly state why it wasn't able to accomplish the task.

2.8. **Category VIII: Three at once.** The command is composed by *three simple actions*, which the robot has to show it has recognized. The robot may repeat the understood command and ask for confirmation. If it can't recognize the command correctly, it can also ask the speaker to repeat the complete command.

3. **Task assignment:** The robot is given the command by the operator and may directly start to work on the task assignment.
4. **Task execution:** The robot must stop the execution of a task and return to its designated position within 5 minutes. Otherwise the robot must be moved to its designated position immediately. If a restart is still available to the team, it can be restarted at the designated position.

5. **Returning:** After accomplishing the assigned task, the robot has to move back to its designated position to wait and retrieve the next command (i.e., go back to 1. without the need of re-entering the arena).

6. **Timing:** The total time allotted to the robot for command retrieval and task execution is 3 $\times$5 minutes. If the robot is not at its designated position after the time has expired, it must be moved at its designated position immediately.

6.1.3. Additional rules and remarks

1. **CONTINUE rule:** Teams are able to use the CONTINUE rule in this test, with all the standard penalties it involves as described in section Section 3.9.

2. **Mixed or random category.** There are extra points if the robot is able to solve a command combining abilities from two or more categories, or if the team chooses the robot to solve a command from a random category. Mixing categories must be requested to the TC two hours before the test.

3. **Number of Teams and Scheduling:** In each test slot, 2 teams may be competing in the arena concurrently. The robots will be tested in an interleaved fashion: The robots will retrieve commands and execute the task one after the other. As stated above, each robot will have a maximum amount of 5 minutes per command (including time for retrieving the command and executing it).

4. **Returning to designated position:** To facilitate a fluent and untroubled performance of the robots, they must return (or being returned) to their designated position before the 5 minutes command time elapses. **If a robot moves from its designated position while another robot is working on a command, it must be immediately dis-**

abled and moved to its designated position. If a restart is still available to the team, it can be restarted at its designated position.

5. **Referees:** Since the score system in this test involves a subjective evaluation of the robot's behavior, the referees are EC/TC members. One referee is assigned to each team to judge performance, to measure the time for working on a command, and to keep track of the overall operating time of the robot.

6. **Category selection:** For every of the three commands given to the robot, the team chooses the desired command category. Please do note that points for showing an ability can only be scored once.

7. **Operator:**
   - The person operating the robot is one of the referees (default operator).
   - If the robot appears to consistently not be able to understand the operator, the referees ask the team to apply the CONTINUE rule (Section 3.9.1).

8. **Inoperative robots:** If a robot gets stuck while trying to accomplish a task during a reasonable amount of time (e.g. 30 seconds), the referee may ask the team to move back the robot to its designated position, proceeding with the next robot.

9. **Restart:** Robots will be restarted at their designated position (starting outside the arena is prohibited). If a robot requires a restart, the referee will proceed with the next robot.

10. **Changing/Charging batteries:** The team may install a charging station at the designated position of the robot, if it does not hinder the other robots. However, the robot must connect itself with the charging station after carrying out a command. Changing batteries or manually connecting the robot with the charging station is allowed during a restart.

11. **Scoring:** Robots are scored by successfully performed ability and full command completion within time.

6.1.4. OC instructions

2h before test:

- Specify and announce the entrance/exit door for each robot.
- Specify and announce the waiting position for each robot.

During the test:

- Help placing items and arranging people upon referee request.

6.1.5. Referee instructions

During the test:

- Generate random sentences.
- Take the command and total time per team.

6.1.6. Score sheet

The maximum time for this test is 40 minutes.

Note 1: Related abilities with similar score are packed together for brevity. Rreferees must mark them and score accordingly.

Note 2: Abilities marked with * score *at most* the suggested points based on the difficulty and performance (following TC criteria).

Action	Score
Command retrieval & Categories	
Understand a command in the 1^{st} attempt (score per generated command)	*3* × *15*
Solved random category / Each extra category (mix)	*15*
HRI	
Answer a predefined question / fetch orders after event detection	*5*
Missing information retrieval / Provide explanations on operator's request	*10*
Natural handover (give or take)	*20*
Manipulation	
Grab/place an object	*5*
Manipulation: two-handed, in narrow spaces*, tiny/heavy/slippery* objects	*30*
Open/close a door/drawer*	*20*
Pouring, pressing, uncapping, turning on/off, twisting	*50*
Memory & Awareness	
Detect an expected event (within a reasonable amount of time)*	*10*
Detect an unexpected event*/Provide sucessful alternate solution*	*20*
Give/use information of the environment/previous commands*	*20*
Navigation	
Follow/guide operator (inside only)	*10*
Follow/guide operator (outside)	*15*
Object recognition	
Count all objects, recognize known/alike object	*5*
Count objects in category / matching description*	*15*
Describe unknown objects	*30*
Find: from description*, occluded (> 50%)	*30*
Find hidden objects, infer category from features	*50*
People, pose and activity recognition	
Gesture detection	*15*
Find or recognizing people	*15*
Person's geneder/pose* recognition	*20*
State the number of people in a group	*15*
Special penalties & standard bonuses	
Contributing with recorded data ($\frac{\sum gathered\ points}{max\ points}$×) (see sec. 3.4)	*10*
Not attending (see sec. 3.10.1)	*-50*
Outstanding performance (see sec. 3.10.3)	*50*
Total score (excluding penalties and bonuses)	*500*

6.2. Open Challenge

During the Open Challenge teams are encouraged to demonstrate recent research results and the best of the robots' abilities. It focuses on the demonstration of new approaches/applications, human-robot interaction and scientific value.

6.2.1. Task

The Open Challenge consists of a demonstration and an interview part. It is an open demonstration which means that the teams may demonstrate anything they like. The performance of the teams is evaluated by a jury consisting of all team leaders, TC and EC.

1. **Setup and demonstration:** The team has a maximum of *seven minutes* for setup, presentation and demonstration.
2. **Interview and cleanup:** After the demonstration, there is another *three minutes* where the team answers questions by the jury members.
   During the interview time, the team has to undo its changes to the environment.

6.2.2. Presentation

During the demonstration, the team can present the addressed problem and the demonstrated approach.

- A video projector or screen, if available, may be used to present a brief (max. 1 minute) introduction to what will be shown.
- The team can also visualize robot's internals, e.g., percepts.

It is important to note that the jury may decide to end the demonstration if there is nothing happening or nothing *new* is happening.

6.2.3. Changes to the environment

1. **Making changes:** As in the other open demonstrations, teams are allowed to make modifications to the arena as they like, but under the condition that they are reversible.
2. **Undoing changes:** In the interview and cleanup team, changes need to be made undone by the team. The team has to leave the arena in the *very same* condition they entered it.

6.2.4. Jury evaluation

1. **Jury of team leaders:** All teams have to provide *one* person (preferably the team-leader) to follow and evaluate the entire Open Challenge.
2. **Evaluation:** Both the demonstration of the robot(s), and the answers of the team in the interview part are evaluated.
   For each of the following *evaluation criteria*, a maximum of *10 points* is given per jury member:
   2.1. Overall demonstration
   2.2. Human-robot interaction in the demonstration
   2.3. Robot autonomy in the demonstration

2.4. Realism and *usefulness for daily life* (Can this robot become a product?)
2.5. Novelty and (scientific) contribution (+contribution to the community)
2.6. Difficulty and success of the demonstration

A jury member is not allowed to evaluate and give points for the own team.

3. **Normalization and outliers**:
   3.1. The points given by each jury member are scaled to obtain a maximum of *250 points* (i.e., multiplied by $^{25}/_{6}$).
   3.2. The total score for each team is the mean of the jury member scores. To neglect outliers, the N best and worst scores are left out:

$$\text{score} = \frac{\sum \text{team-leader-score}}{\text{number-of-teams} - (2N+1)}, \quad N = \begin{cases} 2, & \text{number-of-teams} \geq 10 \\ 1, & \text{number-of-teams} < 10 \end{cases}$$

6.2.5. Additional rules and remarks

1. **Start signal:** There is no standard start-signal for this test.
2. **Abort on request:** At any time during the demonstration, the jury may interrupt and abort the demonstration:
   2.1. if nothing is shown: in case of longer delays (more than one minute), e.g., when the robot does not start or when it got stuck;
   2.2. if nothing new is shown: the demonstrated abilities were already shown in previous tests (to avoid dull demonstrations and push teams to present novel ideas).

Team-team-interaction:

An extra bonus of up to 50 points can be earned if robots from two teams (4 robots maximum, 2 from each team) successfully collaborate (robot-robot interaction).

1. This bonus is earned for both teams.
2. The robot(s) of the other team must only play a minor role in the total demonstration.
3. It must be made clear that the demonstrations from the two teams are not similar, otherwise the points cannot be awarded.
4. In case a team receives two (or more) bonuses, the maximum bonus will be taken.
5. The collaboration is possible even if one of the two teams has not reached Stage 2.
6. A team not participating in Stage 2 receives no bonus points for this test.

Inter-league collaboration : Inter-league collaboration must be announced to the OC at least one day before the test. Teams participating in multiple @Home Leagues does receive no bonus for cooperation. Standard Platform robots are allowed to take part in the Open Challenge of the Open Platform League, but Open Platform robots can *not* participate in any Standard Platform League's test. In the same sense, DSPL robots are not allowed in SSPL and vice versa.

For sake of clarity, please consider the following example: Let be A, B two teams participating in RoboCup @Home where

- Team A participates in SSPL.
- Team B participates in both SSPL and OPL.

- Team A and B have qualified into Stage II.

Then, by aplying the *Inter-league collaboration Rule* (See Section 6.2.5) the following statements can be concluded:

- B OPL can not participate in A SSPL's open challenge.
- B OPL can not participate in B SSPL's open challenge.
- A SSPL can participate in B OPL's open challenge. Team A and B get a bonus because A ¡¿ B.
- B SSPL can participate in B OPL's open challenge. There is no bonus because B = B.

6.3. Restaurant

The robots are tested in a real environment such as a real restaurant or a shopping mall. There are *two* robots helping clients in the restaurant at the same time.

6.3.1. Focus

This test focuses on online mapping, safe navigation in previously unknown environments, gesture detection, human-robot interaction, and manipulation in a real environment.

The robot will need to create its own map from the environment and then move within it to handle human requests, such as delivering drinks or snacks, while people are walking around. As this test is performed with 2 robots (2 teams, each with their own 1 robot) in parallel, the robots will also have to avoid each other.

6.3.2. Setup

1. **Location:** A real restaurant fully equipped with a "Professional Barman" i.e. the operator and at least three tables with "Professional Clients".

6.3.3. Task

1. **Start:** The robot starts at a designated starting position. After the start signal is given, the robot may look around to keep an *eye* on the tables. The location of the tables is not taught to the robot via some training phase.
2. **Calling:** A guest will ask for the robot's attention by waving *and* calling it out using voice. The robot must state out loud that it has detected the call. In case both robots notice the same call, the *Professional Barman* will tell one of the robots to take the order. The barman will say the robot's name followed by "Take the order" e.g. "R2D2, take the order". The other robot will simply have to wait for another call. If the robot *not* commanded to take the order still goes, it will be commanded to wait (e.g. "C3PO, Wait"). In case the robot keeps going after that, the emergency button will be used to stop the robot.
3. **Ordering**: The robot must ask the person what he or she wants to order. See Orders below for details about ordering.
4. **Avoiding random person:** At any time while going to any of the tables or to the *Kitchen*, a person may step on the robot's path. It is expected of the robot to avoid that person or stop and wait for it to move away.
5. **Delivering phase:**
   5.1. **Repeating the order:** Once again in the kitchen, the robot recites the orders for each table (e.g. *"Hamburger with fries for table A and Orange juice for table B"*, to the *Professional Barman*. The *Professional Barman* will serve the order and place it into a tray on the Kitchen-bar. If the barman cannot understand the order that the robot repeats, he cannot hand out the order and no points can be awarded for reciting the order.
   5.2. **Grabbing a beverage:** The robot must grab a can of the appropriate drink from a set of cans on the Kitchen-bar.

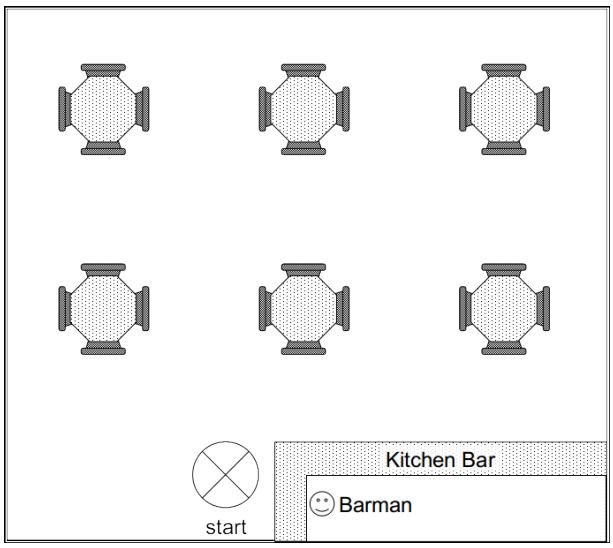

Figure 6.1.: Restaurant test: example setup.

5.3. **Grabbing a combo:** The robot must carry a tray with the ordering from the kitchen-bar. Teams must indicate beforehand whether the robot is able to grasp the plate itself, whether it needs a tray or whether the plate needs to be handed to the robot.

5.4. **Delivery:** The robot must place the order on the table. If the robot is not able to do this, the robot is allowed to hand over the order, but the client is not allowed to shift his/her chair or stand up. The robot must help the client, not the other way around.

6. **Next customer, please:** When the robot is in the kitchen, the *Professional Barman* will ask the robot to either find a new client to serve or to stop the test. The barman will either tell the robot "R2D2, Wait" to make it wait for another client or "R2D2, Stop the test" to end the test for that robot.

Orders: The menu offers Beverages and Combos. An order may be a Beverage or Combo. Some guest(s) will order a Combo while another will order a Beverage. A Combo is a combination of two of the food items from the set of objects 3.2.5, e.g. "noodles with peanuts" or "noodles and peanuts". Guests also prefer to state their order in a natural way, as they would in a restaurant operated by humans.

6.3.4. Additional rules and remarks

- **Safety!** This test takes place in a public area. That is, there may be people standing, sitting or walking around the area throughout the test. The robot is expected to not even slightly touch anything and is immediately stopped in case of danger.
- **Referees and guidance:** For safety reasons, the referees in this test are TC members. One of the referees follows the robot and is always in reach of the emergency button.
- **Start:** There is no fixed start signal in this test, it starts when both robots are ready (though within a reasonable time).

- **Order:** The way the user provides information to the robot is up to the robot's team. A natural interaction is preferred.
- **Location:** This test can be arranged in any real restaurant or shopping mall. If this is not possible, the test can be conducted in an arbitrary room containing the appropriate locations. The only requirement is that this room is not part of the arena and that the teams do not know the room beforehand. The exact location, including the object and delivery locations, will be defined by the technical committee on site (and in corporation with the local organization). In addition, to avoid unnecessary time investment for navigation, the distances between tables and the "Kitchen Bar" will be minimal.
- **Disturbances from outside:** If a person from the audience (severely) interferes with the robot in a way that makes it impossible to solve the task, the teams may repeat the test immediately.
- **Learning tables:** Of course, it can only be sure that a robot correctly remembered where an order is suppposed to be delivered when it is able to go there after grabbing the order.
- **Instruction:** The robot interacts with the operators, not the team. That is, the team is only allowed to (very!) briefly instruct the *Professional Barman*
  - How to the tell the robot the order has been served

  It is not allowed to the team to instruct the clients on how to get robot's attention. It shall be done in a natural way like when interacting with a human waiter.
- **Kitchen-bar:** The *Kitchen-bar* will be a table located at the restaurant's kitchen, next to the place where the robot started. The robot may ask on which side of the robot the Kitchen-bar is, e.g. on its left or right side. It may ask this at any time, but it is better if the robot infers this itself. It has the following setup.
  - **Barman:** A *Professional Barman* (member of the TC) will be at the other side of the Kitchen-bar to take the order provided by the robot and serve it in the official tray.
  - **Beverages:** Beverages will be located on the Kitchen-bar next to the *Professional Barman*.

6.3.5. Data recording

Please record the following data (See Section 3.4):

- Audio
- Commands
- Mapping data
- Images
- Plans

Referee instructions

The referee needs to

- Prepare orders for each client in advance, so that there can be no confusion. These orders must also be available at the kitchen.

6.3.6. Score sheet

The maximum time for this test is 15 minutes.

Action	Score
Start	
Infer on which side the bar is	*5*
Calling phase	
Noticing a call	*2 × 10*
Ordering phase	
Arriving at the table of the calling person	*2 × 5*
Looking at the calling person	*2 × 10*
Taking an order	*2 × 10*
Avoiding a person crossing the robots' path	*2 × 10*
Grabbing phase	
Reciting the order for the table	*2 × 5*
Grasping the correct drink	*2 × 15*
Picking up the plate	*2 × 20*
Delivery phase	
Getting close to the correct table with an order	*2 × 10*
Delivering the drink by placing it on the correct table	*2 × 15*
Delivering the drink by handing it over conveniently for the client	*2 × 5*
Delivering the plate by placing it on the correct table	*2 × 20*
Delivering the plate by handing it over conveniently for the client	*2 × 5*
Special penalties & standard bonuses	
Contributing with recorded data ($\frac{\sum gathered\ points}{max\ points}\times$) (see sec. 3.4)	*10*
Not attending (see sec. 3.10.1)	*-50*
Outstanding performance (see sec. 3.10.3)	*28*
Total score (excluding penalties and bonuses)	*285*

6.4. Set a table and clean it up [DSPL & OPL]

The robot has to set the table for a meal, and clean it up afterwards.

6.4.1. Focus

This test focuses on HRI, semantic mapping, object perception and manipulation.

6.4.2. Setup

- **Location:** This test takes place inside the apartment, in a room with a table of the kind people sit to have a meal (e.g. kitchen's table).
- **Cutlery:** Cutlery and other appliances like carpets and napkins are stored inside a closed cupboard or similar type of furniture (e.g. inside a drawer).
- **Food:** Food and cleaning utensils are placed close to the table (e.g. in a rack or locker).
- **Cupboard:** The cupboard used to store the cutlery is located close to the table.
- **Table:** The table may have some objects on top of it, like a carpet or a plate.

6.4.3. Task

(a) Typical arena

(b) Typical objects

Figure 6.2.: Table settings: (a) occidental, and (b) Japanese.

Part I: Setting up the table

1. **Fetching command:** The operator requests the robot to set up the table. Optionally, the robot may ask the operator *what has to be served*. The operator replies with the randomly selected (and undisclosed) option.
2. **Setting the table:** The robot must safely and neatly place (i.e. without colliding with any existing object) all missing objects required for the meal. For example, carpet, fork, knife, spoon, and dish.
3. **Serving the meal:** If the robot asked the operator what to serve, it must proceed to place the order requested by the operator (e.g. pour cereal and milk in the bowl, or placing some slices of bread in the dish).
4. **Correcting object positions:** The operator will change the position of two objects on the table at any time before the placement of the last one. The robot must realize this change and rearrange the table to look neat.

Part II: Cleaning up the table

1. **Fetching command:** After the meal, the operator requests the robot to clean up the table.
2. **Clean the table:** After being instructed, the robot returns the objects to their original location, *i.e.,* where they were found in the first place.
3. **Scrub spots and spills:** The robot must detect spots and spills on the table and clean them up using a cleaning cloth.

6.4.4. Additional rules and remarks

1. **Startup:** The robot starts with a single voice command or via a start button (Section Section 3.8.8). If the robot is unable to start it must be removed immediately.
2. **Collisions:** Slightly touching the table is allowed, as well as slightly pushing some objects. However, driving over the objects or any other form of a major collision is not allowed, and the referees directly stop the robot (Section Section 3.8.1).
3. **Custom food:** Teams are allowed to provide their own food for preparing meal. However, it must be inspected by the TC at least 2 hours before the test.
4. **Object list:** A total of 6 objects is considered, 3 of them considered easy to grasp (e.g., a cereal box, a cup, and a plate), while the remaining 3 hard to grasp (e.g., cutlery, napkins, and a basket with bread).
5. **Opening the door:** If the robot is unable to open the door by itself, it may kindly ask the operator to do so.
6. **Spots and Spills:** The referees will mess up the table right after it has been set, by spreading breadcrumbs, spilling some liquid, adding spots of jam, etc. It must be clear the robot has detected them and is trying actively to clean them, even though the cleaning may be unsuccessful.
7. **Task variation:** The team may provide the referees a written set of at least 2 options for serving a meal (e.g. cereal and milk, sandwiches, toasts, Coffee and bread, etc.). These options must be written as possible answers to the robot question (step 1 in section 6.4.3). The correct execution of the specified variation should be clearly visible, e.g., choice of an object placed on the table.

6.4.5. Data recording

Please record the following data (See Section 3.4):

- Images of recognized objects
- List of moved items

6.4.6. Referee instructions

The referee needs to

- Clean up any remaining object on the table.
- Place the objects the predefined locations.
- Close the closet door.
- Choose a random meal variation (when available).
- Ask the team whether they implemented a meal variation and choose randomly one of them.

6.4.7. OC instructions

During Setup days:

- Provide official cutlery and appliances for training.

One day before the test:

- Announce the food location.

- Announce the location for the cutlery and appliances.

2 hours before the test:

- Collect from teams the set of meals their robot can serve.
- Place all objects and clear the table.

6.4.8. Score sheet

The maximum time for this test is **10 minutes**. A maximum of 6 objects is considered in this score sheet. 3 of those are easy to grasp, 3 are difficult to grasp (for a robot)

Action	Score
Meal variation	
For asking for the meal variation and confirming the choice	*10*
Grasping objects	
For each successful grasp of an **easy**-to-grasp object (lifting it up to at least 5 cm for more than 10 seconds)	*6 × 10*
For each successful grasp of an **hard**-to-grasp object (lifting it up to at least 5 cm for more than 10 seconds)	*6 × 15*
Placing objects	
For each successful placement of an **easy**-to-grasp object anywhere on the table (safely stands still for more than 10 seconds)	*3 × 10*
For each successful placement of an **hard**-to-grasp object anywhere on the table (safely stands still for more than 10 seconds)	*3 × 20*
For appropriately executing the operator's choice	*30*
For each collision of an object with another one on the table	*6 × -5*
Cleaning up the table	
For each successful placement of an **easy**-to-grasp object to its original location (safely stands still for more than 10 seconds)	*3 × 10*
For each successful placement of an **hard**-to-grasp object to its original location (safely stands still for more than 10 seconds)	*3 × 20*
For successfully cleaning up dirt and spill on the table	*40*
Bonus	
Open the door without human help	*15*
Special penalties & standard bonuses	
Contributing with recorded data ($\frac{\sum gathered\ points}{max\ points}\times$) (see sec. 3.4)	*10*
Not attending (see sec. 3.10.1)	*-50*
Outstanding performance (see sec. 3.10.3)	*39*

Total score (excluding penalties and bonuses) *390*

6.5. Tour guide [SSPL only]

The robot guides spectators to the audience area and answer their questions after explaining what's @Home about.

6.5.1. Focus

This test focuses in safe outdoor navigation, people detection, gesture recognition, unconstrained natural language processing, and Human-Robot Interaction

6.5.2. Setup

- **Location:** This test takes place outside the arena in a public space close to the @Home area.
- **Other people:** There are no restrictions on other people walking by or standing around throughout the complete task.
- **In Parallel:** This test can run in parallel, with several teams tested simultaneously.

6.5.3. Task

1. **Start:** The robot waits at a designated starting position for the referee to give the start signal. When the referees start the time, the team is allowed to (briefly) provide some remarks about the robot's operation. After the instruction, the referee gives the start signal to the robot.

2. **Finding spectators:** The robot starts moving to an open area and looks for (preferably large) groups of people. Once located the robot must approach to the spectators while calling for their attention in a *friendly* way.

   People trying to call the attention of the robot (e.g. by waving or shouting) have priority over those just walking by despite the number of the crowd. The robot may also approach to a single person.

3. **Greeting an spectator:** Once the robot has gained the attention of the spectators, it must introduce itself (i.e. saying it's name), and greet one of the spectators as customary in the venue's country (e.g. bowing, handshaking, waving, etc).

   Note that all spectators may also want to greet the robot. The robot is expected to be polite and continue greeting on demand.

4. **Guiding the spectators:** The robot must gently ask the spectators to follow it to any of the @Home audience areas and guide them there. Should the people not be willing to follow the robot, it must thank them and start looking for another group of spectators.

5. **Explaining the league:** Once at the @Home audience area, the robot must ask the spectators to take seat. The robot proceeds to *briefly* introduce RoboCup@Home and explain the Social Standard Platform League's objectives.

6. **Answering questions:** At the end of the speech, the robot asks for questions from the spectators regarding what it just explained, answering at least two of them. The robot is allowed to rephrase questions before answering them.

6.5.4. Additional rules and remarks

1. **Safety First!** The robot will be stop at the slightest possibility of a human being harmed or molested. The robot must not force interaction with humans, nor scare them or make them feel uncomfortable.

2. **Referee guard:** During the entire test, a referee will be following the robot from behind for keeping people safe and for scoring purposes.

3. **Approaching to spectators:** When approaching to people the robot should act in a natural way by reducing its velocity as it approaches to the people. The robot must look safe and friendly.

   Shall the people flee, the robot must not chase them.

4. **Spectators:** Spectators are people attending to the venue to see the competition with no restriction of any kind, therefore, their numbers, grouping, and behaviour are not controlled by the league. Were the case of no spectators available, volunteers can be used instead.

5. **Bilingual robots:** Robots are allowed (and encouraged) to interact with people in a language other than English. In such cases, the robot must utter the English equivalent right after synthesising the localized sentence.

   Notice that spectators may prefer to ask questions in their native language when interacting with a bilingual robot. In such cases, the robot must translate the question for the Referee to understand it and answer the question in both languages.

6. **Handshaking:** When handshaking, the robot must stay at a safe distance from the people (e.g. about 1.5m) and reach out its *hand*, but it must be a human, not the robot, who accepts and completes the handshake. If the human refuses to shake hands, the robot must retreat its manipulator immediately.

7. **Disturbances from outside:** If a person from the audience (severely) interferes with the robot in a way that makes it impossible to solve the task, the team may repeat the test immediately.

8. **Show must go on:** If the robot has engaged with a group of spectators when the allotted time for the test elapses, the robot is allowed to continue and finish the demonstration. However, no points are scored once the test is over.

6.5.5. Referee instructions

The referees need to

- Follow the robot at any time.
- Immediately stops the robot when considered necessary.
- Verify that the given answers are correct.

6.5.6. OC instructions

2h before test:

- Recruit volunteers for the test (just in case).
- Announce the Start Location for the robots.

During the test:

- Keep at least one area free in the audience area for robots to perform there.
- Send volunteers to join the Q&A session to ask questions if necessary.

6.5.7. Score sheet

The maximum time for this test is **10 minutes**.

Action	Score
Engaging spectators	
Find an spectator (or group)	*30*
Greet an spectator (handshake)	*20*
Greet and get greet by an spectator (bowing or waving)	*10*
Guiding spectators	
Convince spectator to follow	*10*
Reach the audience area	*40*
Q&A Session	
Finish talk without loosing spectators	*10*
Each correctly understood question	*2* × *70*
Each correctly answered question	*2* × *30*
Bilingual interaction	
Bilingual engaging	*10*
Questions in 3^{rd} language	*2* × *25*
Question answered also in 3^{rd} language	*2* × *10*
Special penalties & standard bonuses	
Contributing with recorded data ($\frac{\sum gathered\ points}{max\ points}\times$) (see sec. 3.4)	*10*
Not attending (see sec. 3.10.1)	*-50*
Outstanding performance (see sec. 3.10.3)	*39*
Total score (excluding penalties and bonuses)	*390*

Chapter 7

Finals

The competition ends with the Finals on the last day, where the five teams with the highest total score compete. The *Finals* are conducted as a final open demonstration. This demonstration does not have to be different from the Open Challenge. It does not have to be the same either.

7.1. Final Demonstration

In the final demonstration, every team qualified for the Finals can choose freely what to demonstrate. The demonstration is evaluated by both a league-internal and a league-external jury.

7.1.1. Task

The procedure for the demonstration and the timing of slots is as follows:

1. **Setup and demonstration:** The team has a maximum of *ten minutes* for setup, presentation and demonstration.
2. **Interview and cleanup:** After the demonstration, there is another *five minutes* where the team answers questions by the jury members.
   During the interview time, the team has to undo its changes to the environment.

7.1.2. Evaluation and Score System

The demonstration is evaluated by both a league-internal and a league-external jury. The final score and ranking are determined by the two jury evaluations and by the previous performance (in Stages I and II) of the team.

1. **League-internal jury:** The league-internal jury is formed by the Executive Committee. The evaluation of the league-internal jury is based on the following criteria:
   1.1. Scientific contribution
   1.2. Contribution to @Home
   1.3. Relevance for @Home / Novelty of approaches
   1.4. Presentation and performance in the finals.
   It is expected that teams present their scientific and technical contributions in both *team description paper* and the *RoboCup@Home Wiki*. In addition, finalist teams may provide a printed document to the jury (max 2 pages) that summarizes the demonstrated robot capabilities and contributions. The influence of the league-internal jury to the final ranking is 25 %.
2. **League-external jury:** The league-external jury consists of people not being involved in the RoboCup@Home league, but having a related background (not necessarily robotics). They are appointed by the Executive Committee. The evaluation of the league-external jury is based on the following criteria:
   2.1. Originality and Presentation (story-telling is to be rewarded)
   2.2. Usability / Human-robot interaction
   2.3. Multi-modality / System integration

2.4. Difficulty and success of the performance
2.5. Relevance / Usefulness for daily life

The influence of the league-external jury to the final ranking is 25 %.

3. **Previous performance:** 50 % of the final score are determined by the team's previous performance during the competition, i.e., the sum of points scored in Stage I and Stage II.

7.1.3. Changes to the environment

1. **Making changes:** As in the other open demonstrations, teams are allowed to make modifications to the arena as they like, but under the condition that they are reversible.
2. **Undoing changes:** In the interview and cleanup team, changes need to be made undone by the team. The team has to leave the arena in the *very same* condition they entered it.

7.2. Final Ranking and Winner

The winner of the competition is the team that gets the highest ranking in the finals.

There will be an award for 1st, 2nd and 3rd place. All teams in the Finals receive a certificate stating that they made it into the Finals of the RoboCup@Home competition.

Appendix A

Speech and Person Recognition in detail

A.1. Questions for Speech and Person Recognition

The questions the robot must answer in the RoboGame test are taken from a small set of predefined trivia questions including information about the arena, the crowd, the list of predefined objects, and the robot's environment.

A generator is publicly available at https://github.com/kyordhel/GPSRCmdGen. The official SPR Command Generator and the official grammars will be made available two months before the competition. However, teams must be aware that the categories, objects and other data is provided for testing purposes only and will adapt to the environment during the setup days.

A.1.1. Question distribution

The questions to be asked in both, the *riddle game* and the *blind man's bluff game* tasks, are distributed in the following proportion:

- One is a predefined question
- Between one and two are about the arena and its status
- Between one and two are about the crowd
- Between one and two are about the list of official objects

However, it is important to remark that **questions won't be asked in any specific order**. This is since the robot must be able to answer any type of question at any given time. For instance, the robot may be asked first about the arena, then about object, later on a predefined question, and finally about the crowd.

A.1.2. Arena Questions

The arena-questions are a set of queries about the features of the RoboCup@Home Arena itself, including its furniture and configuration (e.g. rooms and locations). The arena is considered to be in its normal state and the robot must answer accordingly, without needing to move and verify the state.

Some example arena-questions are:

1. Where is the shelf? → *The shelf is in the kitchen*
2. Where is the plant? → *The plant is in the living room*
3. How many chairs are in the dining room? → *There are six chairs in the dining room*

A.1.3. Crowd & Operator Questions

The crowd-questions are a set of queries about the features of the crowd the robot observed at the very beginning of the test.

Some example crowd-questions are:

1. Size of the crowd
2. Number of children

3. Number of male or female people
4. Number of people waiving or rising arms
5. Number of people standing, sitting or lying
6. How old do you think I am? → *I think you are 23 years old.*
7. The sitting person was a man or woman? → *The sitting person was a man.*
8. Am I a man or a woman? → *I couldn't tell.*

A.1.4. Object Questions

The object-questions are built on basis of the features of the predefined objects used during the competition and their categories. Such features include color, shape, size, type, weight, category, predefined location, etc. The arena is considered to be in its normal state and the robot must answer accordingly, without needing to move and verify the state.

Some example object-questions are:

1. What's the smallest food? → *The egg is the smallest in the food category.*
2. What's the lightest drink? → *The Coke Zero, is lighter than water.*
3. Where can I find the tray? → *The tray is in the shelf.*
4. Where can I find the beer? → *I put it into the fridge for you, master.*
5. What's the color of the shampoo? → *The shampoo is blue.*
6. What's the color of the sponge? → *The sponge is yellow and has square pants.*
7. What objects are in the closet? → *The shampoo, soap, the sponge and a cloth.*
8. How many objects are in the shelf? → *There are five objects in the shelf.*
9. Do the objects in the cupboard belong to the same category? → *Yes. They are all food.*

Please note that some questions may refer to a previous question or answer.

Predefined Questions

In addition to the other questions, 10 predefined trivia-questions will be announced during the setup days.

Some example predefined-questions are:

1. What day is today?
2. What is your name?
3. What is your team's name?
4. What time is it?
5. In which year was RoboCup@Home founded?
6. What was the last question?

Please note that some questions may refer to a previous question or answer.

A.2. People setup in *blind man's bluff game*

People in the *blind man's bluff game* is arranged by the referees in random fashion, but considering each league's robot capabilities. In every turn, the referee chooses which person will ask the next question. This person can be the same one who asked a question in the previous turn; but no chosen person can be in front of the robot.

Standing *in front of* the robot: A person is considered to be standing *in front of* the robot when is located in the cone of approximately 60° (approximated range of $\left[-\frac{\pi}{6}, \frac{\pi}{6}\right]$, with zero facing forward) which middle is aligned (and facing) whatever part of the robot that functionally operates as front or face for Human-Robot interaction purposes, and with center in the before mentioned central part of the robot.

Standing *behind* the robot: A person is considered to be standing *behind* the robot when is located in the cone of approximately 60° (approximated range of $\left[\frac{5\pi}{6}, \frac{7\pi}{6}\right]$, with zero facing forward) which is in direct opposition, i.e. mirrors, the front of the robot described in the preceding paragraph.

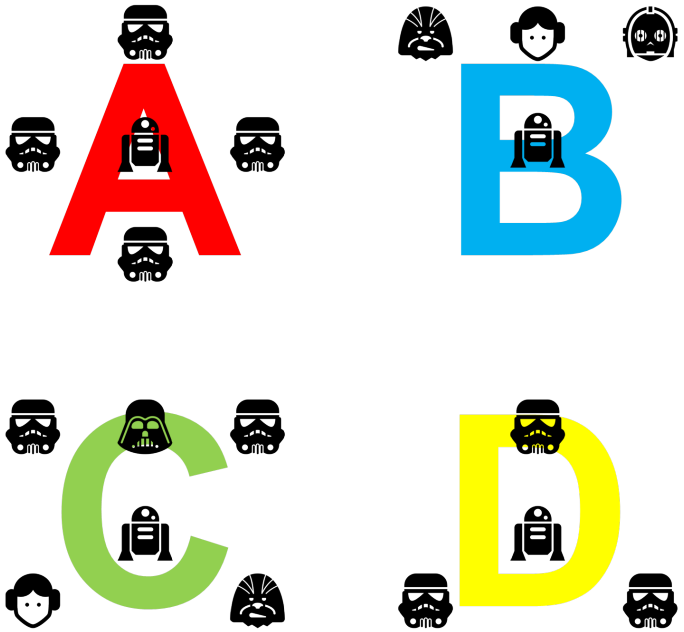

Figure A.1.: Examples of people distribution in the *blind man's bluff game*.

A.2.1. People layout in DSPL

People arrangement for robots competing in the Domestic Standard Platform League will follow a layout similar to B in Figure A.1; however, the number of people can vary.

Please note that after each question people will stay in place and proceed with the game without awaiting for the robot to reposition. This means that people might not be standing anymore facing the robot after it has turned. Also, since the people arrangement is linear, the distance between the robot and the spoken person can be larger than 1 meter.

A.2.2. People layout in OPL

People arrangement for robots competing in the Open Platform League will follow a layout similar to C in Figure A.1; although, the number of people can vary, all of them will be initially encircling and facing the robot. In this layout no person is allowed to be standing straight behind the robot, but slightly to the left or to the right.

Please note that after each question people will stay in place and proceed with the game without awaiting for the robot to reposition. This means that people might be standing straight behind the robot after it has turned. Also, although the referee will try to keep an even distance between the robot and the people, depending on the crowd size the 1 meter limit can be exceeded.

A.2.3. People layout in SSPL

People arrangement for robots competing in the Social Standard Platform League can follow a layout similar to either B or C in Figure A.1, but the number of people can vary.

In B-like (linear) layouts, since the people arrangement is linear, the distance between the robot and the spoken person can be larger than 1 meter.

Regarding C-like (circular) layouts all of them will be initially encircling and facing the robot. In this layout no person is allowed to be standing straight behind the robot, but slightly to the left or to the right.

Please note that after each question people will stay in place and proceed with the game without awaiting for the robot to reposition. This means that people might be standing straight behind the robot after it has turned, or beyond the 1 meter limit.

Appendix B

GPSR in detail

B.1. Command Generation

General Purpose Service Robot commands are generated randomly using the official [EE]GPSR Command Generator and grammars publicly available at https://github.com/kyordhel/GPSRCmdGen. The official [EE]GPSR Command Generator and the official grammars will be made available two months before the competition. However, teams must be aware that the categories, objects and other data is provided for testing purposes only.

For each command to be executed, the Team Leader must choose a Command Category, namely Category I, Category II, or Category III. If the Team Leader knows *a priori* that the robot won't be able to execute the generated command, is advised to inform the operator immediately in order to proceed with the next command, saving this way valuable time for the task execution.

B.2. Command retrieval explained

The robot has to show it has understood the given command by stating all the required information to accomplish the task. For this purpose, the robot may repeat the understood command and ask for confirmation. It is not required to repeat the command word by word; rephrasing the command is allowed. For instance, if the robot is instructed to "place a coke onto the tray", the robot may either say: *"You want me to place a coke on the tray. Is that correct?"* or *"do you want me to deliver a coke to the tray?"*.

If The robot can't correctly recognize the given command, it is allowed to request the operator to repeat the command up to three times. After three failed attempts, a new command is generated. The team may opt to use a custom operator or bypassing speech recognition (Section 3.9.1) at any time, but each generated command will be given to the robot no more than three times. Only three different commands are generated for a robot, if the robot fails to recognize all three commands (i.e. nine attempts), the test ends immediately.

When a robot has partially understood the command, it is allowed to ask the operator for additional information (e.g. *"did you say apple juice or pineapple juice?"*).

B.2.1. Missing information

When a given command lacks of information required for accomplishing the task, the robot should request for that missing part. For instance, if the robot is instructed to *"offer a drink to the person at the door"*, it may ask *"which drink should I deliver to the person at the door?"* It is also possible that the robot simply confirms the command and takes a random drink from the drinks location, but in those cases, the jury will consider the command as if it were from an inferior/lower category.

B.2.2. Wrong information

Some Category III commands contains erroneous information. In these cases, the robot should

- be able to realize such an error while trying to carry out the task, get back to the operator, and clearly state why it wasn't able to accomplish the task; or
- be able to solve the problem by means of an alternative, reasonable solution.

For example, lets assume the robot is commanded to *"move the orange juice from the fridge to the dinner table"*, but in the fridge there are only the apple juice and the milk, while the orange juice lies in the stove. The robot may either explain to the operator that there are no orange juices in the fridge, or search the kitchen for the orange juice, grasp it from the stove and deliver it to the dinner table.

B.3. Command categories explained

All possible actions has been classified previously by the TC according to their difficulty. For each of the three given command, the team may choose from the following categories:

B.3.1. Category I

This category comprehends easy-to-solve tasks with a low difficulty degree, involving indoor navigation, grasping known objects, answering questions (from the predefined set of questions), etc.

Some examples are:

- *Tell me how many beverages are in the shelf.*
- *Put the crackers on the kitchen table.*
- *Tell the time to Ana at the bedroom.*
- *Tell me the name of the person at the door.*
- *Bring me the apple juice from the counter.*

B.3.2. Category II:

Tasks with a moderate difficulty degree. This category involves following a human, indoor navigation in crowded environments, manipulation and recognition of alike objects, find a calling person (waving or shouting), etc.

Some examples are:

- *Tell me how many beverages in the shelf are red.*
- *Put the banana on the kitchen table.*
- *Count the waiving people in the livingroom.*
- *Follow Ana at the entrance.*
- *Tell me the name of the woman in the kitchen.*

B.3.3. Category III:

This category comprehends challenging tasks involving dealing with incomplete information, environmental reasoning, feature detection, natural language processing, outdoors navigation, pouring, opening doors, etc.

The commands generated for this category heavily depends on the League and are detailed as follow.

Advanced manipulation [DSPL and OPL]

Some examples are:

- *Pour some cereals in the bowl.*
- *Go to the bathroom* (Bathroom's door is closed).
- *Bring me the milk from the microwave* (The milk is inside the microwave)

Incomplete and erroneous information [All Leagues]

These commands are almost the same as the ones of categories I and II, but either the information given is incorrect or incomplete. This means that executing the command as it has been given is not possible. The robot must come up with an appropriate solution to execute the operators' command.

Some examples are:

- *Follow John* (John's location is not specified).
- *Bring me a drink* (The exact drink is not specified).
- *Bring some snacks to Mary* (Neither Mary's location nor the snack are specified).
- *Find Ana at the bedroom and tell her the time* (Ana is lying on the floor or standing under the door frame).
- *Bring me a drink from the fridge* (There are no drinks in the fridge, but in the kitchen table).

Other tasks [All Leagues]

Some examples are:

- *Follow me and then go to the kitchen* (Operator takes the robot to the audience area).
- *Give me the left most object from the shelf.*
- *Count the drinks on the table.*
- *Tell me how many girls there are in the livingroom.*

Appendix C

E^2GPSR in detail.

C.1. Command Generation

EEGPSR commands are generated randomly using the official [EE]GPSR Command Generator and grammars publicly available at https://github.com/kyordhel/GPSRCmdGen. The official [EE]GPSR Command Generator and the official grammars will be made available two months before the competition. However, teams must be aware that the categories, objects and other data is provided for testing purposes only.

For each command to be executed, the Team Leader must choose a Command Category. If the Team Leader knows *a priori* that the robot won't be able to execute the generated command, is advised to inform the operator immediately in order to proceed with the next command, saving this way valuable time for the task execution.

C.1.1. Random Category Selection

The team leader may request **once** to the referee to give to the robot a command from a random category. Extra points are given if the robot is able to successfully execute the given command. The random category selection is a *one-time* request.

C.1.2. Mixing Categories

The team leader may request to the Technical Committee to test the robot with commands involving abilities from two or more categories. Mixing categories must be requested to the TC two hours before the test, and once requested there is no step back. Extra points are given if the robot is able to successfully execute the given command.

C.2. Command retrieval explained

The robot has to show it has understood the given command by stating all the required information to accomplish the task. For this purpose, the robot may repeat the understood command and ask for confirmation. It is not required to repeat the command word by word; rephrasing the command is allowed. For instance, if the robot is instructed to "place a coke onto the tray", the robot may either say: *"You want me to place a coke on the tray. Is that correct?"* or *"do you want me to deliver a coke to the tray?"*.

If The robot can't correctly recognize the given command, it is allowed to request the operator to repeat the command up to three times. After three failed attempts, a new command is generated. The team may opt to use a custom operator or bypassing speech recognition (Section 3.9.1) at any time, but each generated command will be given to the robot no more than three times. Only three different commands are generated for a robot, if the robot fails to recognize all three commands (i.e. nine attempts), the test ends immediately.

When a robot has partially understood the command, it is allowed to ask the operator for additional information (e.g. *"did you say apple juice or pineapple juice?"*).

C.3. Categories explained

This section explain each of the categories of the test and provides examples on the given commands and expected abilities.

It is important to remark that there is no script or predefined way to solve the tasks, being most of them of ambiguous nature. It is up to the team to choose how to solve each tasks accordingly with the robot's capabilities.

C.3.1. Category I: Advanced Manipulation

Tasks from this category require handling objects into small or narrow spaces, manipulate tools, buttons, panels, and doors; two-handed manipulation, or eye-hand coordination.

Task examples

- Grasping objects from a box.
- Placing objects into a microwave.
- Shutdown the TV using its remote control.
- Transporting a tray.
- Pouring cereal in a bowl.
- Opening a bottle (twist, uncap, etc.).

Command examples

- Hand me a coke from the fridge (the coke is inside the fridge).
- Bring me some flakes in a bowl.
- Put this book into the drawer.
- Turn off the TV.
- Put all the beverages on the dinner table.

C.3.2. Category II: Advanced Object Recognition

Tasks from this category require describing unknown objects, recognize objects from description, identify occluded objects and from the distance.

Task examples

- Counting objects in a shelf.
- Describing unknown objects.
- Finding object from far distance.
- Finding objects from a description.
- Infer unknown object's class (category, e.g. snacks) from features.
- Object detection and recognition of occluded or hidden objects (behind of, inside of, etc.).

Command examples

- Bring me the biggest pill bottle from the kitchen counter.
- Bring me the bookcase's right-most object.
- Describe the objects on the drawer to me.
- Tell me how many red apples are in the basket on the kitchen table.
- Count the snacks in the shelf and tell me how many there are.

C.3.3. Category III: Navigation & People Tracking

Tasks from this category require following or guiding people in crowded environments or through narrow spaces. The navigation may take place either inside or outside the arena.

Task examples

- Following a person inside an elevator.
- Guiding a person to the toilet.
- Going through a multitude while following or guiding a person without loosing them.
- Avoiding people crossing or standing by while guiding or following.
- Performing real time mapping and localization.

Command examples

- Guide the person at the entrance to the kitchen.
-
- Follow the person in front of you and go to the bedroom (operator will guide the robot outside the arena, so it will need to go back).

C.3.4. Category IV: People & Activity Recognition

Tasks from this category require memorizing a person's features, describing unknown people, recognize people from description, and being able to find people hiding or from the distance.

Task examples

- Describing a person in certain specific location.
- Delivering objects to a person that matches the given description.
- Reporting number of people in a room matching given description.
- Finding people performing certain activity.
- Finding people whose face or body or partially occluded or not facing the robot.

Command examples

- Describe the person at the door.
- Ask Joe to come here (Joe is sleeping in the sofa).
- Take this coke to the girl [in the living room] wearing a red sweater.
- Tell me how many standing people there are in the dining room.
- Go to the living room and follow the waving person.
- Tell me what John is doing (John is reading a book).

Meeting new people

Say the generated command is *ask Joe to come here*, since the robot has no knowledge of who is Joe, it is expected to ask "*how can I recognize Joe?*" Two answers are possible:

- ***Meet Joe:*** The person named *Joe* will stand in front of the robot and follow robot's (not team's) instructions for training. The robot must announce when it has completed memorizing that person before proceeding to execute the command.
- ***Joe is the...*** A description indicating how to recognize *Joe* is given to the robot. Retrieved information must be confirmed.

Remark: Category III Overlap. There may be given extra points for requesting further information about a named person and conducting a training or associating the name with the description.

Remark: Category IV Overlap. Referees will use the same names for the same people, for which the robot may interact with the same person more than once. There are extra points if the robot can identify in a later command a previously learned name and successfully recognize that (same) person without training or asking for description (see score sheet).

C.3.5. Category V: Incomplete Information

In this category, the commands given do not include all the information necessary to accomplish the task

Incomplete information

The robot gets a command that does not include all the information necessary to accomplish the task. The actual commands will be under-specified by, for example:

- only giving the class of the object ("bring me a drink") or location ("guide me to the table"), and not the actual object or location, or
- not providing the location (or its class).

The robot can ask questions to retrieve the missing information about the task, but is not required to. In the questions the robot has to make clear what it has already understood, e.g., tell the operator that it has understood *to bring a particular beverage can*, but not *where the can is* located in the arena. The robot may also simply start searching.

Task examples

Tasks from this category are the same of GPSR (see Section B.3.1 and Section B.3.2), it is how the robot is commanded what changes.

Command examples

- Bring me a drink (unspecified which drink).
- Guide a person to the kitchen (unspecified where is that person).
- Bring some snacks to the table (unspecified which table).

C.3.6. Category VI: Erroneous Information

The robot gets a command that contains erroneous information. The robot should be able to realize such an error while trying to carry out the task, and try to carry on an alternative solution. If the robot is unable to solve the problem, it must go back to the operator, and clearly state *why* it wasn't able to accomplish the task.

Task examples

Tasks from this category are very much like the ones in GPSR (see Section B.3.1, Section B.3.2 and Section B.3.3).

Command examples

- Bring me a coke from the fridge.
  The coke is on the kitchen table.

- Take Ana from the sofa to her bed.
  Ana is lying on the floor, unconscious, next to the sofa.

C.3.7. Category VII: Memory and Environmental Reasoning

The robot gets a command that does not include all the information necessary to accomplish the task, assuming that the missing information is already known by the robot or can be (easily) obtained from the environment, for example:

- Requesting to interact with an object or person ("bring a coke to Mary") with which the robot has interacted before (the robot guided Mary to the bedroom).
- Requesting to observe the environment to gather the information required to accomplish the task.

The robot should be able to realize previously performed changes to the environment. If the robot is unable to solve the problem, it must go back to the operator, and clearly state *why* it wasn't able to accomplish the task.

Task examples

Tasks from this category are very much like the ones in GPSR (see Section B.3.1, Section B.3.2 and Section B.3.3), it is how the robot is commanded what changes.

Command examples

- Take the orange juice from the shelf and give it to Mary.
  The robot just guided Mary to the bedroom.

- Bring me the coke from the fridge.
  The operator already has the coke on their hand.

- Check which beverages there are in the counter and offer one to James at the sofa.
  Counter has milk, beer, crackers, and apples.

C.3.8. Category VIII: Three at once

Command from this category are composed of *three simple actions*, which the robot has to show it has recognized. The robot may repeat the understood command and ask for confirmation. If it can't recognize the command correctly, it can also ask the speaker to repeat the complete command.

Tasks from this category are much alike the ones in GPSR (see Section B.3.1 and Section B.3.2), requiring to master basic skills. Since commands must be accomplished as quick as possible, in this category speed is the key.

Command examples

- Go to the kitchen counter, take the coke, and bring it to me.
- Bring the chips to Mary at the sofa, tell the time and follow her.
- Find a person in the living room, guide them to the kitchen and follow them.
- Take the chips from the counter, find a person in the bedroom, and go to the entrance.

C.4. Scoring

The EEGPSR scoresheet is not straight-forward to understand, for there are too many possibilities to be listed and they would be hard to find. In consequence, this section explains how scoring is performed in EEGPSR by providing an example.

It is important to remark that in EEGPSR, that points for each demonstrated ability be scored only once. Exception to this rule are Speech Recognition, Natural Language Understanding, and Error and Event Handling; key abilities that are core of this test. being often considered. The referees will often consider the best execution of a given demonstrated ability (e.g. object recognition) as long as the performance looks consistent and not simply a lucky strike.

Another important remark is that referees can grant partial points for a demonstrated ability regarding the performance of the robot (e.g. precision, accuracy, speed, consistency) and the difficulty of the task. In the same way, referees can forfeit points if the task execution looks tweaked or over scripted, as well in those cases in which the robot is performing actions to harvest points or exploiting the rules instead of trying to efficiently solve the task.

C.4.1. Example round 1

Robot Rosie enters the arena and awaits for a command. Two hours before the test, team Jetsons requested the referee to give Rosie a command mixing Categories I and II, and V. The following (random) command is given:

- *Bring some food to Elroy.*

As Rosie has no idea which kind of food she should deliver to Elroy nor where he is, she asks for the missing information:

- `Where can I find Elroy?`
- *Elroy is at the bed.*
- `Which kind of food should I give to him?`
- *Some Space O's in a bowl.*

After answering Rosie's questions the referee scores 25 points to the Jetsons; fifteen for understanding the command at the very first attempt, and only ten for retrieving missing information even though the Robot asked two questions. This is because a robot can score only once per demonstrated ability and Rosie has proven it can request missing information. Rosie will score no more points for making questions.

Continuing with the example; Rosie navigates then to the kitchen and starts looking for the *bowl* and *Space O's cereals*. Since Rosie is a nice maid, she places the bowl in a tray she just put on the table. However, the cereals are nowhere within sight or where they should be, so Rosie looks deeper for them and opens one of the doors of the cupboard, finding finally the Space O's. Rosie takes the box, drives back to the table and pours the cereals into the bowl, spilling some of them in the tray, and leaving the box on the table.

In the meanwhile, the referee gave Rosie:

30pts For placing the tray on the table (2-handed manipulation).
20pts For manipulating the the bowl.
20pts For opening the cupboard's door.
50pts For finding the Space O's cereals (hidden object).
5pts For picking the Space O's cereals from the cupboard.
5pts For safely placing the Space O's cereals on the table.
25pts For pouring the Space O's cereals into the bowl but spilling.

Please note that no points are given for recognizing the tray or placing it on the table, as well as no bonus is given for placing the bowl on top of the tray as using the tray was not requested; however, the referee gives 20 points to Rosie for handling (pick and place) the bowl as its round shape makes it hard to manipulate. For pouring the cereals, Rosie could have achieved up to 50 points, but she spilled the content so only partial scoring is given.

Continuing with the example; Rosie announces that the bowl is harder than the tray for her to transport, so she will deliver the bowl using the tray. After successfully picking up the tray, Rosie heads towards Elroy's room, where she finds the boy who takes the bowl from the tray. After completing the command, Rosie goes back to the start point, and finishes the round. Yet she explains to the operator what she did, making emphasis in the fact that the Space O's were not on its place, but hidden.

In the meanwhile, the referee gave Rosie:

30pts For moving the tray (2-handed manipulation) as it was reasonable and required by the robot.
30pts For accomplishing a command involving 3 categories ($base + 2 \times 15$).

Since finding Elroy at the bed presents no difficulty at all, and it was the boy who took the bowl from the tray (i.e. no handover), no additional points were scored. Furthermore, no additional score is given for remembering changes in the environment since neither the robot was requested to provide any further explanation, nor a command requiring to use that information was given.

1^{st} **Round score:** 240 points.

C.4.2. Example round 2

The robot is waiting inside the arena for a command. Two hours before the test, team Jetsons requested the referee to give Rosie a command mixing Categories IV and VI, and VII. The following (random) command is given:

– *Ask the white-haired person wearing a pink blouse in the dining room where is Elroy and deliver him the Space O's.*

After confirming the command, Rosie heads towards the kitchen table and grasps from there the Space O's box she just poured in the past round. Then she goes to the dining room where George is having breakfast. The robot speaks out loud that there are no people wearing pink in the dining room and that she will try in the living room before asking where to search.

The referee has scored Rosie as follows:

15pts For 1^{st} attempt command retrieval.
20pts For remembering the last location of the *Space O's* (kitchen table).
20pts For detecting the target is not at the dining room and proposing an alternate, reasonable, working solution to the problem (search living room).

Going back to the example; Rosie arrives to the living room where Judy and Jane watch TV. Judy is a white-dyed teenager wearing pink, while Jane is a blond woman dressed in purple. Confused, Rosie approaches Jane and asks where to find Elroy:

Rosie: `Where can I find Elroy?`
Jane: *Elroy is at school.*
Rosie: `I can't reach there. What should I do now?`
Judy: *Could you please give me the Space O's?*
Rosie: `Here you are.`

Finally, Rosie goes back with the operator and explains that it delivered the Space O's to the person upon request because Elroy was not at home, so it was impossible to deliver them. The round is over and the operator scores as follows:

0pts For finding the described person, since Judy was described but the robot approached Jane.
20pts For realizing the action was impossible to be carried out.
10pts For fetching for command from Judy (action after event detection).
20pts For realizing it was in possession of the object and proceed to immediate deliver (use of environment information to accomplish command).
20pts Space O's natural handover.
30pts For accomplishing a command involving 3 categories ($base + 2 \times 15$).

Please notice that, although it may seem otherwise, the rule of not scoring twice for the same ability is preserved. First, the robot uses its memory to recall where the cereals were left; while latter it uses environmental information (i.e. the fact that is holding the Space O's) to accomplish the command. The same applies to event and error handling. The robot first scores for controlling erroneous information that can be controlled (the people was not where it was supposed to) and scores for controlling a situation for which there is no reasonable solution, also able to react to a command from a third source.

2^{nd} **Round score:** 165 points. **Total score:** 395 points.

Appendix D

Example Skills

The following section presents a list of *Example Skills* with an high degree of difficulty which can be exploited during the *Open Demonstrations* (See Section 3.7.5. Other skills not on this list (yet) may be added as well. If you want to do so, please let the TC know via email (tc@robocupathome.org) for their inclusion on the RuleBook so all teams may also show this skill.

Please note that these examples are to illustrate the level of complexity and applicability that should be shown. For instance, "Handle a pan" is listed in the category of *Complex manipulation*, but it is extensive to handling pans, pots, woks and any other cookware with handles.

D.1. Skills by category

D.1.1. Complex manipulation

- Cook a meal.
- Manipulating panels/switches/knobs.
- Use/open a fridge/stove/blender/microwave/washing machine.
- Iron clothes.
- Move a movable object (pole, chair, table).
- Pouring liquids/powders.
- Operate a water tap.
- Handle a pan.

D.1.2. Complex vision

- Read text from a newspaper.
- Handle glass/shiny-metallic objects.
- Recognize moods, activities, age, gender.
- Label unknown objects.

D.1.3. Complex navigation

- Navigate in (very) crowded environments.
- Navigate difficult terrain.
- Climb stairs.
- Push a wheelchair.

D.1.4. Robot-Human Interaction

- Collaborative robot-human manipulation.
- Maintaining a conversation.
- Learning actions on-the-fly.
- Learning objects from humans e.g. "This object is a ..." with an open vocabulary.

- Following a human by grasping its hand.
- Explain the robot abstract concepts (why people love sunny days).
- Arrange unknown random people for a nice photo (no occlusions).

D.1.5. Complex action planning

- Separate clothes for laundry (e.g. by color)
- Arrange a dish-washer.
- Take a cup from the cupboard whose location has changed, is closed, or the path to it is blocked (e.g. by a chair).
- Light the way out with a lamp during a general power off.
- Arrange unknown random people for a nice photo (no occlusions).
-

D.1.6. Mapping

- Learn/create a (3D) map on the fly.
- Semantically annotate a map on the fly
- The robot enters a completely changed arena (furniture moved or even changed), explores it and is told to go to e.g. a table that is moved or added.

Appendix E

Arena decorations

The following is a list or suggestions, not strict requirements, for decorating a RoboCup@Home arena:

- Side table
- Table lamp
- Bowl
- Vase
- Plant
- Table runner
- Coffee/tea maker
- Pillows in various colors
- Mirror
- Paintings
- Posters
- World map
- Towels
- Towelhangers
- Closet/shelf
- Standing lamp
- Bedspread
- Basket with lid
- (Storage)Basket
- Serving tray
- Cups
- Mugs
- (Wine)Glasses
- Plates
- Cutlery
- Various utensils
- Picture frames
- Wallclock
- Bedside alarm clock
- Candles with holders
- Books

Abbreviations

EC	Executive Committee	5, 8, 9, 31
Finals	final demonstration	32
OC	Organizing Committee	6, 17, 28, 30, 41
TC	Technical Committee	67
TC	Technical Committee	5, 8, 9, 11, 28, 29, 31, 32, 35, 39, 43
TDP	team description paper	16

Index