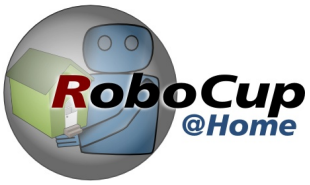

RoboCup@Home

Rules & Regulations

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This is the official rulebook of the RoboCup@Home competition 2017. It has been written by the 2016/2017RoboCup@Home Technical Committee (in alphabetical order): Loy van Beek, Kai Chen, Dirk Holz, Loreto Martinez Luz Sanchez, Mauricio Matamoros, Hideoki Nagano, Caleb Rascon, and Sven Wachsmuth.

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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)
- Jose Martinez-Carranza (National Institute for Astrophysics, Optics and Electronics, Mexico)
- Kathrin Evers
- Hideoki Nagano (Tokyo City University, Japan)
- Wei Shuai (University of Science and Technology of China, China)
- Rodrigo Ventura (Institute for Systems and Robotics, Instituto Superior Tcnico, 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
- Francisco Javier Rodriguez Lera
- Raphael Memmesheimer (University of Koblenz, Germany)
- Alexander Willem Moriaty
- Jeffrey Too Chuan Tan
- Josemar Rodrigues de Souza (Bahia State University, Brazil)
- Ryuichi Ueda

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/listinfo.cgi/robocup-athome-robocup.org

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.

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 **??**.

Figure 1.1.: Toyota HSR

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.

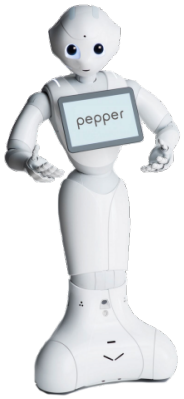

Figure 1.2.: Softbank / Aldebaran Pepper

The robot to be used in the SSPL is the Softbank/Aldebaran Pepper, shown in Figure 1.1.

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

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.

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. 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 challenges, so e.g. if the robot scores manipulation points during the navigation 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.

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 challenge 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 3.8.8). 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 challenges. 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

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

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

room to 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 trays, baskets, bowls, 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 two containers (a transport container such as a tray and a pouring container such as a bowl) which will be available for training during the setup days.

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 both hands.

Custom containers. The goal of containers is to encourage **bi-hand manipulation**. However, 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 3.9.2).

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. **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 standarized 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 compontents 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 3.9.2).

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.

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 arificial 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 3.8.7, 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 3.8.7).

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.

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 challenges. 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 challenge, specific data is to be gathered and stored on a USB stick. After all attempts at a challenge 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 challenge and thus each challenge 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 the continue rule. 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. Using an *on-board microphone* is mandatory for communication with the robot.

    - **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. This 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*.

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.

[1] If the total number of teams is less than 12, up to 6 teams may advance to 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 3.9.1).
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.
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 3.9.1) and extraordinary penalties (see Section 3.9.2) 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 6.3.
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 3.8.12).

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. 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.

3.8.5. 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.

3.8.6. 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.

3.8.7. Start signal

Different challenges are started in different ways, according to what would make the most sense in the application setting. Before a challenge 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 challenge starts when the door is opened by a referee, not by a team member.
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.

3.8.8. 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.

3.8.9. 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.

3.8.10. 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 3.9.2).
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.

3.8.11. 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.

3.8.12. 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.

3.8.13. 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).

3.8.14. Restart

1. **Stage 1** has no restarts but features multiple attempts at a challenge. If a robot fails during an attempt, the attempt ends. A robot has several (ideally 3, depending on available time in the scheduele) attempts for each challenge. An attempt cannot be restarted. E.g. if a robot fails halfway through an attempt at the navigation challenge, the attempt is over,

the robot is moved out of the test area and may prepare for the remaining attempts at the challenge.

2. **Stage 2** does have restarts for challenges:
   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

3.8.15. Continue rule: Bypassing Automatic Speech Recognition

Giving commands to the robot is an important part of many tests. RoboCup@Home fosters natural human-robot interaction through gestures and speech, such that speech is the primary modality to give complex commands to the robot. Automatic speech recognition (ASR) however can be very difficult in the international competition environment of RoboCup. Because active robots are preferred over robots that are passive due to failing ASR, the team is allowed to provide means to bypass ASR via an Alternative method for HRI (Section 3.8.15). Points for getting accommand are only given if the robot understoond the command through speech.

Procedure

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

1. **Default:** When the referee generates a command for the robot, it will be read out loud by the operator to the robot. 100% of the points for getting the command will be awarded, if not stated otherwise.
2. **team member:** If this fails, a team member may speak the command to the robot if this was not the case already. 75% of the points for getting the command will be awarded, if not stated otherwise.

1. **Number of Continue's:** Unless stated otherwise, the referee chooses to apply and initate the steps of the procedure listed above.
2. **Time:** The time is neither restarted nor stopped while the Continue rule is applied.

3. **Multiple Continue's:** The Continue rule will applied by the referee as often as required to make the robot be active. The penalty involved makes this unpreferable to the team and the usage should not be preferred, incentivizing the team to provide a proper means of ASR.

Alternative methods for Human-Robot Interaction (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 is 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.

Further:

- **Award:** The best alternative is awarded the Best Human-Robot Interface award (Section 1.7.2).
- **Points:** Using an Alternative method for HRI does **not** yield points for understanding a command. This is justified, as the amount of points for getting a command is relatively small compared to executing a command. Without offering an alternative, the robot would be unable to continue and thus score no points at all.

Below are some suggested alternatives for ASR:

- A touch-sensitive designed interface.
- Other types of natural interaction such as gestures.
- ...

What a good custom ASR alternative is loosely defined on purpose to foster and allow creativity.

3.9. Special penalties and bonuses

3.9.1. 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*.

3.9.2. 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 challenge (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.

3.9.3. 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.

3.10. 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 (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 (< 20) or best 50% (≥ 20)	*advance* → Best 5 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 3.8.7). 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 and Continue Rule(Section 3.8.15).
   - ***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. Storing Groceries

The robot must help put the newly bought groceries in the right place. The owner of the robot will put the items on a table and the robot helps the owner by putting the groceries in the right place in the cupboard. What the right place for an item is defined by the objects already in the cupboard: objects of the same type must be placed together. For example, the new pack of cookies from the table must be placed by the almost empty pack cookies in the cupboard.

In the cupboard and on the table, there will be both known, alike and unknown objects.

5.1.1. Goal

The robot has to identify, grasp and correctly place several objects at different heights or positions. To start the storing the groceries, the robot needs to open the cupboard.

5.1.2. Focus

This test focuses on object detection, manipulation and object recognition.

5.1.3. Setup

In the arena, there will be a table and cupboard close together, where the robot does not have to spend a lot of time driving between the two.

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. The robot will start somewhere between the cupboard and the table. The cupboard has at least 5 shelves between 0.30m and 1.80m from the ground.
2. **Cupboard:** The cupboard contains 10 objects from the Scenario Objects 3.2.5.
3. **Door:** The cupboard has a single door, which is closed initially. The robot may ask a human to open the door, after which a referee will open the door.
4. **Table:** 10 objects from the Scenario Objects 3.2.5 will be placed on the table. If not all 10 objects fit the on the table, remaining objects can be added during the test.

Please note that there may be more than one object in each shelf to fit all objects in, especially after the robot fills the shelves.

5.1.4. Task

1. **Opening door:** The cupboard's door is closed and must be opened. Note that quickly opening the door also yields a small time advantage.
2. **Searching for objects:** The robot approaches the table from its nearby starting position and starts searching for objects.
3. **Grasping objects:** Any object found on the table by the robot may be grasped by it. Before or right after grasping the object, the robot may announce which object it has found.
4. **Placing objects:** After grasping the object, the robot has to safely place it (Section Section 3.2.5) near the item of the same class in the cupboard. The object must stay there for at least 10 seconds.

5.
6. **Repeat:** This repeats until the time is up or all groceries are stored.

5.1.5. Additional rules and remarks

1. **No setup:** There is no setup time.
2. **Startup:** The robot must be started with a simple voice command or via a start button (Section Section 3.8.7).
3. **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.
4. **Collisions:** Slightly touching the the cupboard is tolerated. 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).
5. **Recognition report:** Robots must create a PDF report file including the list of recognized objects with a picture showing the object and the object name/label. This file may be stored on a USB-stick on the robot which is given to the TC after the test. The PDF file name should include the team name and a timestamp. Furthermore, it must be unmistakable which label belongs to which object. Objects must also be recognizable in the report by a human (TC) so that it can be scored. An overview of the shelf and/or table with bounding boxes and labels attached to the bounding boxes is handy for the TC to score. False positives in the report (labeling an object which is not an object but e.g. the edge of the shelf) are penalized.
6. **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.
7. **Unknown objects:** A significant amount of objects are unknown objects. A correct label for these may constitute be:
    - 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. “label0” for one pair and “label1” for another).
    - Labeling unknown objects with a new, sensible label for objects.

5.1.6. Data recording

Please record the following data (See Section 3.4):

- Images
- Plans

5.1.7. 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 in the table and corresponding ones in the cupboard: 3 known objects, 2 alike and 5 unknown objects.

5.1.8. Score sheet

The maximum time for this test is 3 minutes. The robot is given 1 extra minute to open the cupboard door. 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.

Action	**Score**
Grasping objects	
For each successful grasp of any object (lifting it up to at least 5 cm for more than 10 seconds)	*5 × 10*
Placing objects	
For each successful placement of an object anywhere in the cupboard (safely stands still for more than 10 seconds)	*5 × 10*
For each successful placement of an object at correct place (near an object of the same class)	*5 × 5*
Recognizing objects	
Every correctly recognized known or alike object in the report file	*10 × 5*
Correctly label unknown objects	*5 × 15*
False positive label	*10 × -5*
Bonus	
Open the door without human help	*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. 3.9.1)	*-50*
Outstanding performance (see sec. 3.9.3)	*25*
Total score (excluding penalties and bonuses)	*250*

5.2. Speech and Person Recognition

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

5.2.1. Focus

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

5.2.2. Setup

1. **Location:** One room of the arena is used for this test.[1].
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.

5.2.3. Task

- **Start:** The robot starts at a designated starting position and announces it wants *to play riddles*.
- **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.
- **Requesting an operator:** After turning around, the robot must state the size of the crowd (male and female count) 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.
- **The riddle game:** Standing in front of the robot, the operator will ask 7 questions from the list.
  The robot must answer the question without asking confirmation. Questions will only be asked only once; no repetitions are allowed.
- **The blind man's bluff game:** 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

  The game will end when the 7th question has been made, following the same distribution as in the riddle game. The robot must answer the question without asking confirmation. Questions may be repeated once.
- *Leave:* The robot leaves the room through the designated door.

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

5.2.4. Additional rules and remarks

- **Continue rule:** Continue rule (Section Section 3.8.15) is not allowed to be used during this test.
- **Asked questions:** The distribution of questions to be randomly asked is a follows:
  - One is a predefined question
  - Two are about the arena and its status
  - Between two and three are about the crowd
  - Between two and three are about the list of official objects

  Question examples see Appendix Section A.
- **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 5.1). In the *riddle game* the operator shall be between -60° and 60° from the robot's center (front range).
- **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.
- **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.
- **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.
- **Standing still operators** Operators are not allowed to move to or turn towards the robot or shout to the robot.
- **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

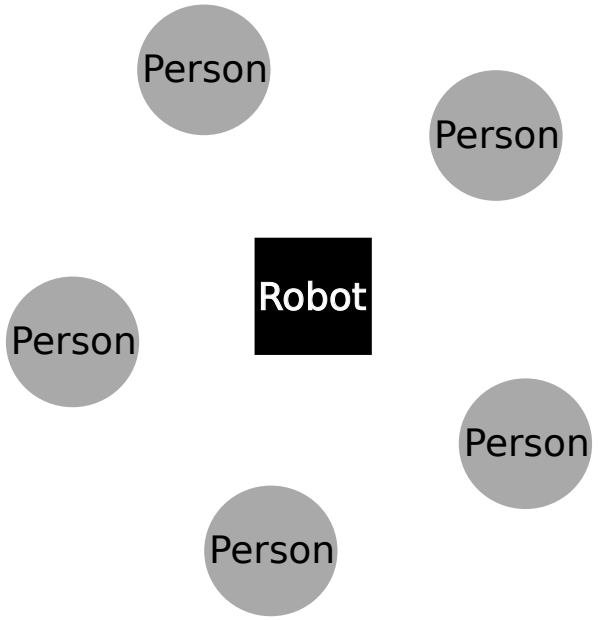

Figure 5.1.: Speech recognition test: person setup around the robot for 2nd part.

5.2.5. Data recording

Please record the following data (See Section 3.4):

- Audio
- Commands
- Images

5.2.6. 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

5.2.7. 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.

5.2.8. Score sheet

The maximum time for this test is 10 minutes.

Action	Score
Crowd	
State crowd's male/female count	*10*
Riddle game	
Correctly answered a question	*7* × *10*
Answering all 7 riddle game question	*5*
Blind man's bluff game	
Answering question on the first attempt	*7* × *10*
Answering question on the second attempt	*7* × *5*
Turned towards person asking the question	*7* × *10*
Answering all 7 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. 3.9.1)	*-50*
Outstanding performance (see sec. 3.9.3)	*22*

Total score (excluding penalties and bonuses) *225*

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. The whole family helps, as well as the robot.

5.3.1. Goal

The robot must bring some items from outside the arena inside the arena.

5.3.2. Focus

This test focuses on following and navigation in an unknown environment.

5.3.3. Setup

The robot starts waiting inside the arena. The operator (the robot's owner) has a set of bags and boxes 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:** Starting location of the robot.
3. **Car:** The robots operator has put the groceries in the trunk of the car after shopping. The car is parked outside the home.
4. **Destinations:** The items must be transported to places where they can be stored. The destinations are various rooms of the arena.
5. **Doors:** All doors in the apartment are open.
6. **Operator:** A "professional" operator is selected by the TC to act as the operator of the robot.
7. **Other people:** There are no restrictions on other people walking by or standing around throughout the complete task.

5.3.4. Task

1. **Start:** The robot is waiting somewhere in the apartment. The operator approaches the robot and tells it to follow. E.g. "Robot, follow me"
2. **Following:** The robot starts following the operator, who guides the robot to the car containing the groceries.
3. **Arrive at car:** When at the car, the operator tells the robot they have reached the car and to remember this location. E.g. "Remember: this location is the car".
4. **Handover groceries:** The operator gives the robot a command to carry something, e.g. a box or a bag. E.g. "Carry this box" The robot puts up its arms and the operator gives the item to the robot.
5. **Command destination:** The operator tells where the given item should go, one of the rooms in the arena. E.g. "Bring this to the kitchen"
6. **Delivery:** The robot then goes inside the house to deliver the item to the destination.
7. **Repeat until time is up:** Then, the robot goes back to the car (by itself, as it must remember where the car is) to bring another item inside.

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

- **Small object:** Small object. For example, someone has dropped a piece of fruit (like an apple or mandarin) while carrying the groceries inside.
- **3D Object:** A bar table, normal table, rolling chair: some object that is wider at its top than on its bottom, thus requiring more than just a laser scanner mounted near the ground to avoid obstacles.
- **Smart obstacle:** A person 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 is speaking with him/her.
- **Moving people:** As the whole family living in the house is helping getting the groceries from the car, additional to the robot there will be some people also going back and forth between the car and various rooms. The robot will encounter these and deal with them. These people are friendly to the robot and will not actively block it but the robot must also not block them.

5.3.5. Additional rules and remarks

1. **Delivering items:** At the destination, the robot may place the bag or box at a convenient location: the floor or a table
2. **Obstacle avoidance:** The robot will encounter some human(s) on the way between the two locations.

5.3.6. Data recording

Please record the following data (See Section 3.4):

- Maps
- Plans

5.3.7. Referee instructions

The referee needs to

- Distribute some objects over some boxes and shopping bags.
- Destignate a few “car parking locations” from which the objects must be carried.

5.3.8. Score sheet

The maximum time for this test is 6 minutes.

Action	Score
Single iteration	
Reach the car	*3 × 10*
Natural handover to accept the item from the owner	*3 × 20*
Understand the commanded destination	*3 × 5*
Reach inside the arena again	*3 × 10*
Reach the destination	*3 × 10*
Put the item at the floor or a nearby table	*3 × 5*
Obstacle avoidance	
Avoiding box-sized object	*5*
Avoiding 3D object (Difficult-to-see object)	*10*
Asking a person to step aside	*5*
Moving away movable object	*30*
Move aside for person	*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. 3.9.1)	*-50*
Outstanding performance (see sec. 3.9.3)	*24*

Total score (excluding penalties and bonuses) *240*

5.4. 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.

5.4.1. 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).

5.4.2. 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 must prove it has understood the given command by repeating it (Please see the remarks about this in section 5.4.3).

5.4.3. 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 continue with a custom operator or apply the CONTINUE rule (Section 3.8.15).
   - With the custom operator, the team can only score 50% of the points for the respective command.
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.).

5.4.4. Referee and OC instructions

2h before test:

- Specify and announce the entrance and exit door

5.4.5. Score sheet

The maximum time for this test is 10 minutes.

Action	Score
Getting instructions	
Understanding the command on the 1^{nd} attempt	*3* × *10*
Understanding the command on the 1^{st} attempt (Custom Operator)	*3* × *5*
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 ($\frac{\sum gathered\ points}{max\ points}\times$) (see sec. 3.4)	*10*
Not attending (see sec. 3.9.1)	*-50*
Outstanding performance (see sec. 3.9.3)	*25*
Total score (excluding penalties and bonuses)	*250*

Chapter 6

Tests in Stage II

All ability and integration tests in Stage II grants 250 points (but the Open Challenge which grants 250) and 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 200 points.

6.1. Robot & team cooperation

We encourage robots and teams to work together when performing challenges. For scoring, points are awarded per subtask. The robot (and thus team) performing the subtask gets the points. For example, in the Restaurant-challenge, 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 challenge in their own turn.

6.2. Set a table and clean it up

Setting up a table for a meal and cleaning it up afterwards is one of the most repetitive tasks in a household environment. How wonderful it would be to have a robot doing it for us? This tasks aims at evaluating the capability of robots at this task.

The task comprises two phases: in phase I, the robot is asked to set up the table, according to an optional variation given by the referee, and in the phase II, the robot is supposed to cleanup the table, returning all placed objects to their original location, including detecting and cleaning spills with a cleaning cloth.

This task takes place in a single room, designated *kitchen,* with a *table,* where the relevant objects are stored, some of then on an open closet and other on a closed closet.

In phase I, the operator requests the robot to setup the table for a meal. In this request, the operator may specify one variation of the meal, e.g., milk or coffee, bread or cookies. The robot should then set the table using items stored in various places of the kitchen, and afterwards it must clean it up, including small spills on the table. Some of the items are easily accessible (e.g., over the kitchen counter) while others may require the opening of doors (e.g., inside a closet). Furthermore, some of these items may constrain the way they are handled by the robot (e.g., avoid pouring contents of a container). These items must be placed on a table reasonably following social conventions in terms of their positions on the table[1]. Midway during placement, the robot owner may change/adjust the position of some of the items; the robot is expected to handle the situation appropriately.

In phase II, the operator requests the robot to clean up the table. This includes both returning the placed objects to their original location, and cleaning up dirt and spills using a cleaning cloth. This requires the robot to memorize the location the objects were originally recognized.

6.2.1. Example

The operator requests the robot to set the table for breakfast. Then, the robot replies asking whether the operator prefers bread or cookies, to which the operator replies preferring bread. Several items are placed on the table: a plate, cutlery, a cup, napkins, a basket with bread, a cereal box, etc. The basket with bread, a napkin, and the cereal box are on the kitchen counter; the plate, the cutlery, and the cup are inside a closet. The robot starts moving these items, one by one, from their original position to the table. Some of these objects pose specific challenges to robot manipulation: the napkin is a flexible object, the bread basket contains bread, thus the robot must hold it with care, the items inside the closet require the closet door to be opened, and the cutlery is non-trivial to grasp. After the bread basket is placed on the table, the robot owner decides to move its place, so the positioning of remaining objects must have this in consideration. Then the robot will await an instruction by the operator to clean up the table. While taking his/her meal, the table gets dirty with a spill. The robot must detect the spill and clean it up using a cleaning cloth. Then, all of the other items are returned to their original locations. The task concludes once the table returns to its original state.

[1] Strict adherence to any social convention is out of the scope of the competition, and thus will not be evaluated.

6.2.2. Goal

The robot has to move a list of relevant objects, with a possible variation stated by the operator, onto the a predefined table in the kitchen. Then it should return all placed items to their original locations and cleanup dirt ansd spills from the table.

6.2.3. Focus

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

6.2.4. Setup

Half of the objects are placed on the kitchen counter, while the remaining ones inside a predefined closet, which is closed before the robot entering the arena. The table should be initially cleared of any objects. The robot will start at a predefined location, away from both the kitchen counter and the table. The team may optionally specify to the referees the variations supported by the robot, with at least two options. The referee then selects one of them randomly, not disclosing the choice.

6.2.5. Task

1. **Requesting the task:** The operator requests the robot to set up the table.
2. **Asking for variation:** (optional) The robot asks the operator for an option, to which the operator replies with the randomly selected (and undisclosed) option.
3. **Searching for objects:** The robot must detect which objects are missing on the table and search for them either on the kitchen counter on inside the closet.
4. **Grasping objects:** The robot must grasp any missing object and move it to the table.
5. **Placing objects:** Each object must be placed in a socially accepted position, not colliding with any object there.
6. **Changing objects position:** The operator will change the position of two objects on the table at any time, before the placement of the last one.
7. **Cleaning up the table:** After the meal, the operator requests the robot to clean up the table. The robot returns the objects to their original location, *i.e.,* where they were found in the first place.
8. **Cleanup dirt and spills:** The robot must detect dirt and spills on the table and clean them up using a cleaning cloth.

6.2.6. Additional rules and remarks

1. **No setup:** The robot must be ready to start the test with a voice command or start button when requested by the referee. There is no setup time.
2. **Startup:** The robot must be started with a single voice command or via a start button (Section Section 3.8.7). If the robot is unable to start it must be removed immediately.
3. **Collisions:** Slightly touching the table. 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).

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. **Task variation:** The team may provide the referees a written set of options for setting up the table. These options must be written as possible answers to the robot question (step 2 in section 6.2.5). The correct execution of the specified variation should be clearly visible, e.g., choice of an object placed on the table.

6.2.7. Data recording

Please record the following data (See Section 3.4):

- Images of recognized objects
- List of moved items

6.2.8. Referee instructions

The referee needs to

- Clean up any remaining object on the table.
- Place the objects on either the kitchen counter or inside the closet, half of them in each one of these two locations. Each one of these locations must contain at least one easy to grasp and one hard to grasp object.
- Close the closet door.
- Ask the team whether they implemented a meal variation, and if yes, choose randomly one of the options, not disclosing the choice.

6.2.9. OC instructions

The Organization must provide:

- the objects, as specified in item **??** of section 6.2.6
- both an open closet and a closet with a door in the kitchen room

6.2.10. 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. 3.9.1)	*-50*
Outstanding performance (see sec. 3.9.3)	*39*

Total score (excluding penalties and bonuses) *390*

6.3. 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.

6.3.1. 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.

6.3.2. 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.

6.3.3. 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.

6.3.4. 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:

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

6.3.5. 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).
3. **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).
   3.1. This bonus is earned for both teams.
   3.2. The robot(s) of the other team must only play a minor role in the total demonstration.
   3.3. It must be made clear that the demonstrations from the two teams are not similar, otherwise the points cannot be awarded.
   3.4. In case a team receives two (or more) bonuses, the maximum bonus will be taken.
   3.5. The collaboration is possible even if one of the two teams has not reached Stage 2.
   3.6. The team which does not participate in Stage 2 receives no points for this test.

6.4. Restaurant

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

6.4.1. 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 in parallel, the robots will also have to avoid each other.

6.4.2. Setup

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

6.4.3. 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.

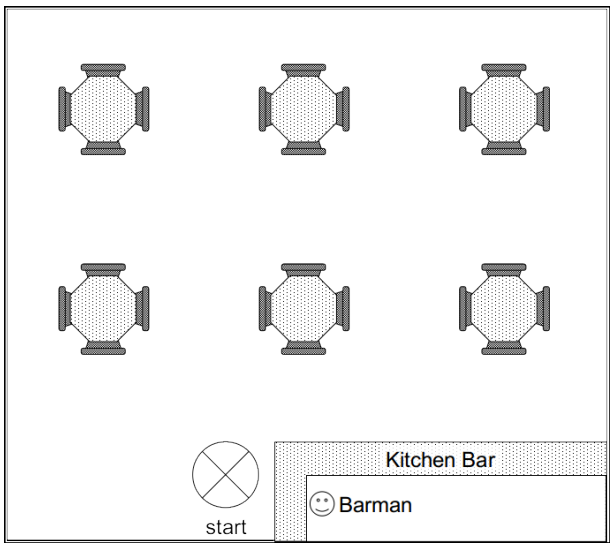

Figure 6.1.: Restaurant test: example setup.

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 challenge. The barman will either tell the robot "R2D2, Wait" to make it wait for another client or "R2D2, Stop the challenge" to end the challenge 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.

6.4.4. 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*.

6.4.5. 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.

6.4.6. 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. 3.9.1)	*-50*
Outstanding performance (see sec. 3.9.3)	*28*
Total score (excluding penalties and bonuses)	*285*

6.5. E^{2}GPSR

(Enhanced Endurance General Purpose Service Robot)

This test evaluates the required robot abilities throughout the Stage I & II tests this (2017) and previous years' rulebook. In EEGPSR the robot has to solve multiple tasks that are chosen randomly by the referees from a larger set of actions, over an extended period of time (30-45 minutes). In other words, tasks are not incorporated into a (predefined) story and there is neither a predefined order of tasks nor a predefined set of actions. The actions to be carried out by the robot are organized in several categories with equivalent complexity but targeting different abilities. It is upto the teams to choose how to execute the command and solving the involved tasks according to robot capabilities. Scoring thereby depends on the complexity of the abilities shown.

6.5.1. Focus

This test particularly focuses on the following aspects:

- No predefined order of actions to carry out.
- Increased complexity in speech recognition.
- More advanced capabilities
- Environmental (high-level) reasoning
- Robust long-term operation.

6.5.2. 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 category chosen by the team (see below). All commands are composed by up to three actions that 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 whole command again.

    2.1. **Category I:** The command is focused in **Advanced Manipulation**.
    2.2. **Category II:** The command is focused in **Advanced Object Recognition**.
    2.3. **Category III:** The robot gets a command focused in Human-Robot Interaction (**HRI**) that does not include all the necessary information to accomplish the task.
    2.4. **Category IV:** The command is focused in **Memory and Awareness**. This category can only be chosen after the team has successfully accomplished another command.
    2.5. **Category V:** The command is focused in **People Recognition** and **Navigation**.
    2.6. **Category VI:** The command is focused in **simple tasks** involving Manipulation, Object Recognition, and Person Recognition.

3. **Task assignment:** The robot is given a command by the operator and may directly start to work on the task assignment. If a robot is unable to perform a command, it should get back to the operator, and clearly state **why** it wasn't able to accomplish the task.

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). The robot can work on at most 3 commands.

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. See the section on scheduling below as well.

7. **Exiting the arena:** When commanded to do so, a robot should leave the arena.

6.5.3. 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 3.8.15.

2. **Number of Teams and Scheduling:** In each test slot multiple teams (preferably 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).

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

4. **Carrying robots:** To carry the robot, at most two team members are allowed in the arena, and the robot must be moved as quickly as possible. To start or restart the robot, at most one team member may operate the robot. The team members moving and operating the robots must leave the arena immediately after the robot is placed or started.

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, as also detailed in the next point.

7. **Scoring:** Points are scored per ability with the total score of the test being the sum of the points scored in each successfully demonstrated ability while solving the tasks (see score sheet). Abilities will be scored considering the best execution only (e.g. successfully grasping scores for *grasping*), with the single exception of collision-free navigation.

8. **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 3.8.15).

9. **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.

10. **Restart:** The number of commands to be given to a robot is three regardless if the restart were used or not. If a restart is required during before the first half of the total time allowed for execute a command elapses, a new command will be generated for the robot to perform. If the first half of the time has elapsed, the team may proceed with the restart but no new command will be generated and the robot must wait for the remaining commands (if any). Robots will be restarted at their designated position, **it won't be allowed to start outside the arena.**

11. **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.

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

6.5.4. 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.

6.5.5. Referee instructions

During the test:

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

6.5.6. Score sheet

Given commands:

Command 1:

Category: 1 2 3 4 5 6 Restart? Custom Operator? Continue? ASR attempts: 1 2 3

Command 1 · 2:

Category: 1 2 3 4 5 6 Restart? Custom Operator? Continue? ASR attempts: □□□

Command 1 · 2 · 3 :

Category: 1 2 3 4 5 6 Restart? Custom Operator? Continue? ASR attempts: □□□

Command 1 · 2 · 3 :

Category: 1 2 3 4 5 6 Restart? Custom Operator? Continue? ASR attempts: □□□

Remark: Abilities marked with * are subjectively evaluated by EC/TC members. Scoring is granted proportionally based on robot performance.

The maximum time for this test is 40 minutes.

Action	Score
Getting instructions	
Understanding the set of actions on the 1^{st} attempt	*40*
Understanding the set of actions on the 2^{nd} attempt	*20*
Understanding the set of actions on the 3^{rd} attempt	*10*
Command given by custom operator (point reduction to ASR)	*0.50* × *-1*
HRI	
Answering a predefined question	*05*
Ask for missing information	*10*
Ask for command after detecting an event	*05*
Explain in detail why the robot could not accomplish a task *	*20*
Natural handover (give or take)	*10*
Manipulation	
Grab an item	*10*
Open door/drawer *	*50*
Place an item	*10*
Pour into a bowl *	*30*
Two-handed transport of tray/bowl *	*20*
Memory & Awareness	
Detect an expected event (within a reasonable amount of time) *	*15*
Detecting an unexpected event*	*25*
Provide information about changes in the environment and/or given commands*	*25*
Navigation	
Follow operator until stopped	*15*
Guide a human to location without loosing him or colliding	*20*
Object recognition	
Describing a set of unknown objects at a location	*25*
Find (and grasp) an object from a description *	*40*
Recognize an object's class correctly	*10*
Search for item at location	*15*
People, pose and activity recognition	
Detect a calling/waving person	*10*
Find a person in a given room	*10*
Recognize a newly learned face correctly	*30*
State the gender of a person	*10*
State the number of people in a group	*10*
State the pose of a person *	*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. 3.9.1)	*-50*
Outstanding performance (see sec. 3.9.3)	*44*
Total score (excluding penalties and bonuses)	*440*

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 other open demonstrations—open challenge and demo 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

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.1. Question distribution

The eight 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
- Two are about the arena and its status
- Between two and three are about the crowd
- Between two and three 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.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).

Some example arena-questions are:

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

A.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? → *None. You are a robot!*

A.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.

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 are they? → *There are four objects in the closet.*
9. Do they belong to the same category? → *They are all cleaning stuff.*

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 RoboCuo@Home founded?
6. What was the last question?

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

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. Th team may opt to use a custom operator or the Continue rule (Section Section 3.8.15).

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:

- *How many beverages are red?*
- *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:

- *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. Focus explained

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 (possible commands are less restricted in both actions/operators and arguments/objects, and can include multiple targets, e.g., "put **an apple, a banana, and the milk** on the kitchen table" or "Ask **Mary** in the kitchen where is **John**").
- More advanced capabilities (e.g. pose and activity detection, unknown object description, door opening, pouring, manipulating a tray, following people in crowded environments etc.).
- Environmental (high-level) reasoning, including:
  - Memory (robot should be able to remember performed actions and their effects).
  - Awareness (unexpected events may occur while the robot is waiting for a command).
- Robust long-term operation.

C.2. Categories explained

This section explain each of the categories of the test and provides examples on how the abilities are scored.

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 according with robot capabilities and skills. For instance, consider that the robot is asked to ***serve breakfast***. A simple approach might be to pick up and deliver a single object in the *food* category (scoring for grasp and place only). A more complex approach would be to ask the operator how breakfast must be served, navigating to the kitchen, pouring cereal into a bowl, put the bowl, a fruit and some milk on a tray, and deliver the tray to the operator himself right after closing the kitchen's door (scoring for requesting additional information, grasping, placing, pouring, two-hand transporting, operating a door, and performing natural handover).

C.2.1. Category I: Advanced Manipulation

Advanced Manipulation involves two-hand manipulation, eye-hand coordination, and operating knobs, handles, buttons, etc. Most of these tasks require a closed control loop between what the robot sees and its manipulators.

Some advanced manipulation examples are:

- Arranging cutlery.
- Opening a bottle (twist, uncap, etc.).
- Opening a door.

- Placing objects inside a box.
- Pouring cereal in a bowl.
- Transporting a tray.

Remark: Teams are allowed (and encouraged) to demonstrate the robot's manipulation skills during this test by performing tasks not mentioned on the rulebook. Such demonstrations, when successfully executed, will be evaluated and scored proportionally by the TC. Please inform a member of such abilities the Technical Committee in advance.

Category I command examples

Below, examples of commands involving advanced manipulation are shown:

- Bring me something for breakfast.
- Bring me some oat, banana and milk in a tray.
- Open the entrance door.
- Put all the beverages in the dinner table.
- Pour the flakes into the bowl and bring it to me.

C.2.2. Category II: Advanced Object Recognition

Advanced Object Recognition involves affordance/feature detection and classification, untrained object recognition, and far-distance recognition. Feature detection for description and detection may involve color, shape, relative size, relative position, and special characteristics of the object such as text, logos, patterns, etc.

Some advanced object recognition examples are:

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

Category II command examples

Below, examples of commands involving advanced object recognition are shown:

- 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.2.3. Category III: HRI & Incomplete Information

This category focuses in commands not including all required information necessary to accomplish the task, making necessary for the robot to interact with the operator.

- **Retrieving missing information:** The robot can ask questions to retrieve the missing information about the task. In the questions, the robot has to make clear what it has already understood and precisely which information is asking for. It is important to remark that several questions may be necessary to fill the gaps in a command.

- **Bypassing ASR:** This category depends heavily in establishing a natural dialog between the robot and the operator, for this reason is highly advised to change of category instead of using the CONTINUE rule Section 3.8.15.
- **Commands difficulty:** Although incomplete, commands involve solving **simple tasks** such as Manipulation, Object Recognition, and Person Recognition.

Remark: Robots may also attempt to solve the command on their own without asking for additional information. For instance, if the operator asks for a beverage but not stating which, the robot may proceed to search for a random drink from the drinks location.

Category III command examples

Below, examples of commands involving HRI & Incomplete Information are shown:

Example Scenario 1 The robot is asked to *Follow Elizabeth and tell the time.* Robot may:

- Ask where is Elizabeth and execute the command.
- Look for Elizabeth and, once she has been found, follow her for later telling the time.

Example Scenario 2 The robot is asked to *Offer a drink to Ana.* Robot may:

- Ask where is Ana, go there, ask Ana which drink does she want, and deliver it.
- Ask where is Ana and which drink must be delivered.
- Ask where is Ana, fetch a random drink and deliver it.
- Find a random drink and start looking for Ana.

Example Scenario 3 The robot is asked to *Guide James to the table.* Robot may:

- Ask where is James, to which table should the robot guide him, and execute the command.
- Ask where is James, go there, and guide him to the dinner table.
- Look for James and, once he has been found, guide him to the dinner table.

C.2.4. Category IV: Memory and Awareness

Memory refers to the robot's ability to remember previous executed tasks and its effects. Directly related with memory, Awareness requires the robot to be aware of changes in the environment as consequence of its actions, as well as being able to detect unexpected events either while idle or during the execution of a task.

Memory and questions on past commands: Unlike other categories, this category cannot be chosen by a team until a command from another category has been (partially) executed. It is up to the referees to decide when a robot is eligible for solving this category. After the first command has been (partially) accomplished, the operator may ask the robot to provide information about its actions and the environment.

Some Memory and Awareness examples are:

- Answering questions about the environment status and changes.
- Approaching a calling (shouting, waving, etc.) operator while idle.
- Detecting the operators fell while guiding the robot.
- Detecting the requested object is taken by another person while grasping.
- Noticing a door has been shut.
- Noticing the operator is not at the designated position.
- Noticing a sleeping person wakes up.

Remark: Teams are allowed (and encouraged) to demonstrate the robot's XXXXX skills during this test by performing tasks not mentioned on the rulebook. Such demonstrations, when successfully executed, will be evaluated and scored proportionally by the Technical Committee. Please inform a member of such abilities the Technical Committee in advance.

Category IV command examples

Below, example scenarios involving Memory and Awareness are shown:

Example Scenario 1 Consider that the robot just delivered the newspaper to John in the living room, possible commands may include:

- Go to the *dinner table*, find *Anna* and tell her who has the newspaper.
- Go to the *coach*, find *James* and answer a *question*.

  Q: The question may be "where is the newspaper?"
  A: A valid answer is "The newspaper is in the living room".
  A: Another valid answer is "I gave it to John in the living room".

Example Scenario 2 The robot has been asked to *Go with the waving person in the dinning room and ask for their name*, which is *Jessica*. Possible commands may include:

- Bring an *apple* to *Jessica*.
- Go to the *coach*, find *James* and answer a *question*.

  Q: The question may be "where is Jessica?"
  A: A valid answer is "Jessica is in the dinning room".

Example Scenario 3 The robot has been asked to *Take the biggest flask from the shelf and put it on the kitchen table*. Possible commands may include:

- Bring me the flask.
- Find John standing next to the *lamp* and answer a *question*.

  Q: The question may be "How many objects there are in the shelf?" (Assume there were 4 before the robot took one).
  A: A valid answer is "There are 3 objects in the shelf".

C.2.5. Category V: People Recognition and Navigation

This category focuses mostly in People Recognition, but considering that guiding and following people involves navigation skills, this ability is also considered. People Recognition involves detecting, remembering, and recognizing people and their characteristics such as gender, age, clothing, size, pose, gestures and activities.

Some People Recognition examples are:

- Counting people in a crowd.
- Counting people in a crowd with an specific pose, gender, age, etc.
- Detecting people pose and gestures.
- Finding and recognizing people from far distance.
- Finding people matching a description (tallest, sitting, wearing specific color, etc.).
- Detecting and recognizing occluded people (behind of, wearing sun glasses, etc.).
- Remembering and later recognizing new people.

Remark: Teams are allowed (and encouraged) to demonstrate the robot's People Recognition skills during this test by performing tasks not mentioned on the rulebook. Such demonstrations, when successfully executed, will be evaluated and scored proportionally by the Technical Committee. Please inform a member of such abilities the Technical Committee in advance.

Category V command examples

Below, examples of commands involving People Recognition are shown:

- Bring a coke to the person with black T-shirt in the couch.
- Go to the living room and follow the waving person.
- Offer something to drink to all the girls in the living room.
- Tell me how many girls are in the living room.
- Tell me how many standing men are in the dinning room.

C.2.6. Category VI: Mastering simple skills

This category, instead of requiring advanced skills, requires mastering the simple ones, for simple task must be solved as quick as possible. In this category, speed is the key.

Category VI command examples

Below, examples of commands involving XXXX are shown:

- Look for Jennifer in the couch and tell her how many apples are in the kitchen counter.
- Find James in the living room, tell the time, and guide him to the Exit.
- Put the chips on the dinner table, go to the entrance, and guide Samantha to the dinning room.
- Take the milk, look for a person in the corridor and answer a question.
- Grasp the coke from the shelf, bring it to the kitchen table, and follow the person in front of you.
- Get the coke from the dinner table and deliver it to Luis at the bathroom.

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