RoboCup@Home

Rules & Regulations

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About this rulebook

This is the official rulebook of the RoboCup@Home competition 2015. It has been written by the 2014/2015 RoboCup@Home Technical Committee (in alphabetical order): Loy van Beek, Kai Chen, Dirk Holz, Mauricio Matamoros, Caleb Rascon, Maja Rudinac, Javier Ruiz des Solar, and Sven Wachsmuth.

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

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Chapter 1

Introduction & Regulations

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:

- Dirk Holz (University of Bonn, Germany)
- Javier Ruiz del Solar (Department of Electric Engineering, Universidad de Chile, Chile)
- Maja Rudinac (Delft University of Technology, Netherlands)
- 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 2015:

- Kai Chen (University of Science and Technology of China, China)
- Caleb Rascon (Universidad Nacional Autnoma de México, Mexico)
- Loy Van Beek (Eindhoven University of Technology, The Netherlands)
- Mauricio Matamoros (Delft University of Technology, The Netherlands)

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 2015:

- Chair: Maja Rudinac (Delft University of Technology, The Netherlands)
- Local chair: Yinfeng Chen (University of Science and Technology of China, China)
- Farshid Abdollahi (Qazvin Islamic Azad University, Iran)
- Sammy Pfeifer (Pal Robotics, Spain)
- Sebastian Meyer zu Borgsen (Bielefeld University, Germany)
- Viktor Seib (Universitaet Koblenz-Landau, Germany)

1.4. Infrastructure

1.4.1. RoboCup@Home Mailinglist

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

<div align="center">

`robocup-athome@lists.robocup.org`

</div>

You can register to the email list at:

<div align="center">

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

</div>

1.4.2. RoboCup@Home Web Page

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

<div align="center">

http://www.robocupathome.org/

</div>

1.5. 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 five highest ranked teams compete to become the winner.

1.6. Awards

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

1.6.1. Winner of the competition

There will be a 1st, 2nd, and 3rd place award.

1.6.2. Innovation award

To honour outstanding technical and scientific achievements as well as applicable solutions in the @Home league, a special *innovation award* may be given to one of the participating teams. Special attention is being paid to making usable robot components and technology 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 innovation award in case no outstanding innovation and no nominees, respectively.

1.6.3. Winner of the RoboZoo

The winner of the *RoboZoo* in the category of performance is given a special *award for wining the RoboZoo*. The decision of which team wins have the robot which performs best is made by an open audience during the RoboZoo test, however, as with the innovation award, the award for winning the RoboZoo is not given in case the team with the highest score didn't show *sufficient performance* according by the the *Technical Committee* (TC) criteria.

1.6.4. Best Test Score Certificate

The team with the highest score in each test in Stage 1 and Stage 2 is given a *Best Test Score Certificate*. To qualify for this award, the obtained score must be at least 70% of the maximum score for that test (see Section 3.8).

1.6.5. Best looking robot

The winner of the *RoboZoo* in the category of appearance challenge is given a special *award for best looking robot*. The decision of which team wins have the best looking robot is made by an open audience during the RoboZoo test.

1.6.6. Most functional robot

The winner of the *RoboZoo* in the category of functionality challenge is given a special *award for most functional robot*. The decision of which team wins have the most functional robot is made by an open audience during the RoboZoo test.

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 all from 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

For qualification, we consider showing the robot(s) successfully solving at least one test of the last year's or current rulebook (excluding ability tests).

For robots moving slowly, it is much appreciated speed-up videos. When doing so, please specify the speed factor being used (e.g. 2x, 5X, 10X). The same is applied for slow motion scenes.

We encourage teams to produce self-explicative videos for a general audience where complex tasks are solved

Please notice that the videos should not last longer than the average time for a test (max. 30 min).

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) 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)

On the last page, after references, please include:

- Name of the team
- contact information
- website
- team members
- photo(s) of the robot(s), unless included before.
- description of the hardware used

- – Provide a brief compact list (2DOF head, 2x7DOF anthropomorphic arms, Pioneer base, etc.).
- – Avoid explaining how your hardware works unless it is part of your research (e.g. we already know what a Hokuyo Laser or Kinect are used for).

- description of the software
  - – Provide a brief compact list (ROS, ROS nav2d, Object Recognition Kitchen, OpenCV, etc.).
  - – Avoid explaining how your software works unless it is part of your research.

The TDP has to be in English, up to eight pages in length and formatted according to the guidelines of the RoboCup International Symposium. 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 content;
- 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.

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 consisting of inter-connected rooms like, for instance, a living room, a kitchen, a bath room, and a bed room.

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.

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

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

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 3.6.8). 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:** Changes will primarily influence the position of objects such as furniture inside the arena while walls are likely to stay fixed. Multiple changes may take place up to completely restructuring the internals of the apartment. The position of named locations (see Section 3.2.8) are not changed when used in a test, e.g., as navigation goal.
   In addition, passages may be blocked and cleared, respectively. One hour before a test slot begins no *major changes* will be made.
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. 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.

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 pre-defined 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 WiFi 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.

Preferably the organizers will try to provide one LAN cable on the desk of each participating team for Internet connection. However, this cannot be guaranteed. If multiple LAN connections are needed, each team has to bring its own LAN hub/switch and cables.

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

3.2.10. Smart Home Devices

The Organizing and Technical Committees in coordination with the Local Organization will compile a list of *Smart Home* official devices that will be available in the arena and can be used in some tests for additional score.

At any time, only the Smart Home devices provided by the Local Organization and approved by the Technical Committee may be used during competition.

Smart Home devices list announcement

The list if Smart Home devices will be provided to teams as soon as it becomes available and has been granted by the Local Organization and approved by the Technical Committee.

This list must be announced at least one month prior the competition. In case that this list does not become available for that date, Smart Home devices may still be present at the arena for testing, but no additional score can be achieved for its use. This is to maintain fair conditions among all teams.

Technical specifications

The list of *Smart Home* official devices will include as much technical information as possible. However, before it becomes available you may assume the following considerations:

1. **Interface:** Most Smart Home devices interface wireless, often via R/F transmitters. When possible, the OC will provide an official interface via the *arena network*.
2. **Operating voltage:** The operating voltage used will be the standard for the place of the competition (e.g.120V/60Hz for North America and 220V/50Hz for Europe). Please note that devices designed for other voltages/frecuencies may burn when plugged to the outlet.
3. **Type of devices:** Mostly Smart Home switches will be used (set on/off, read can not be guaranteed). For high bandwidth devices such as microphones or video cameras, an official interface (such as a ROS topic or web service) will be provided via the *arena network*.

Availability & Scoring

All test has been designed to optionally allow the use of Smart Home devices and even grant bonus scoring for using this option. However, robots must be able to continue operating normally when there are no Smart Home devices available. Therefore, it is unacceptable that a robot stuck while trying to operate those devices.

As stated in Section 3.2.9, organizers cannot guarantee reliability and performance of wireless communication. Therefore, in case of malfunction or communication problems with the Smart Home devices, or any other issue which may affect scoring, no claims will be accepted by the EC/TC/OC, nor test will be repeated. The decision on if a team given points for using *Smart Home* devices, is conducted by the *Technical Committee* (TC), and it reserves the rights of discarding Smart Home related scoring.

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 3.7.2).

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.
4. **RoboZoo:** In the *RoboZoo* both robots can be used simultaneously as long as they fit into the cage.

3.3.3. 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.

3.3.4. 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).

3.3.5. Start button

1. **Requirements:** As stated in Section 3.6.7, 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 3.3.4), 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 3.6.7).

3.3.6. Appearance and safety

Robots should have a nice product-like appearance, be safe to operate 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.

3.3.7. 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. 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*, *RoboZoo*, 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, but have to be inside the arena, i.e., not on its periphery.
8. **Wireless LAN:** The use of networks other than the *arena network* (see Section 3.2.9) is strictly prohibited.
9. **External microphones:** *External microphones*, hand microphones, and headsets are not allowed. Using an *on-board microphone* is mandatory for communication with the robot.

3.5.   Organization of the competition

3.5.1.   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 open audience demonstration called *RoboZoo*. Those *Proficency Tests* (*Ability Tests*, and *Integration Test*) are performed at least 3 times each one.
2. **Stage II:** The best *50% of teams with full integrated capabilities*[1] (after Stage I) advance to *Stage II*. Here, more complex abilities or combinations of abilities are tested. In order to advance to Stage II a team must successfully solve 3 out of *Proficency Tests* in Stage I. The *Open Challenge* is the open demonstration in Stage II.
3. **Final demonstration:** The best *five teams* (after Stage I and 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.

3.5.2.   Number of tests

1. In *Stage I*, the *maximum number of tests* that a team can participate in is *six (6)*.
2. In *Stage II*, the *maximum number of tests* that a team can participate in is *four (4)*.

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[1]If the total number of teams is less than 20, up to 10 teams may advance to Stage II

3. None of the tests is mandatory, except for the *Robot Inspection* test (see Section 4.4).
4. Teams have to indicate to the *Organizing Committee* (OC) in which tests they are going to participate. Otherwise, they are automatically added to all test schedules and may receive a penalty when not attending (see Section 3.7.1).

3.5.3. Schedule

1. **Tests:** The *Organizing Committee* (OC) provides schedules for all tests and teams.
2. **Slots:** The tests will be held in *test slots* of approximately two hours.
3. **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.
4. **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*.

3.5.4. Score system

1. **Stage I:** The maximum total score (excluding special penalties and bonuses) in *Stage I* is *1000 points*.
   1.1. ***Proficiency Tests*:** Each proficiency test is run three times. The maximum total score is calculated as the average of the best two attempts for that test.
   1.2. **RoboZoo:** The maximum score for *RoboZoo* is *50 points*.
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 *200 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 3.7.1) and extraordinary penalties (see Section 3.7.2) 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.).

3.5.5. Open Demonstrations

1. **Stage I:** The *RoboZoo* is the open demonstrations in *Stage I*.

    1.1. Teams can demonstrate freely chosen abilities.

    1.2. The performance is evaluated by an open audience.

    1.3. The *RoboZoo* is described in Section 5.5.

2. **Stage II:** The *Open Challenge* is the open demonstration in *Stage II*.

    2.1. To participate in the *Open Challenge*, a team needs to participate in at least one regular *Stage II* test.

    2.2. Teams can demonstrate freely chosen abilities.

    2.3. The performance is evaluated by a jury consisting of the *Technical Committee* (TC).

    2.4. The *Open Challenge* is described in Section 6.2.

3. ***Finals*:** The competition ends with a final demonstration.

    3.1. The concept of the final demonstration is the same as that of the *Open Challenge*, but the performance evaluation is different.

    3.2. 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.

    3.3. Members of the external jury are selected by the *Executive Committee* (EC) on site.

    3.4. 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.

3.6. Procedure during Tests

3.6.1. 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.

3.6.2. 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 3.6.12).

3.6.3. 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.

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.

3.6.4. 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.

3.6.5. 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 3.6.1) 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.

3.6.6. 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.

3.6.7. Start signal

1. **Opening the door:** Unless stated otherwise, the cue for the robot to enter the arena and start the test is the opening of the door by a referee.

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

3.6.8. 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.

3.6.9. 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.

3.6.10. 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 3.7.2).

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.

3.6.11. 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.

3.6.12. 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.

3.6.13. 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).

3.6.14. Restart

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. **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.
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.
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.
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

3.6.15. Bypassing Automatic Speech Recognition: Continue

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. Due to the sequential nature of many tests and the difficulty of ASR in the international competition environment of RoboCup, the team

is allowed to take up to 2 alternative means to provide a command to the robot, for which the robot continuously fails to recognize the spoken command. These alternative means should be approved by the TC during the *Robot Inspection* test (see Section 4.4).

In future competitions, this rule will be gradually removed. Hence, solutions are encouraged that either resolve the ASR failure through spoken dialogs or solving the task in an alternative way (no penalty), or that use appealing modalities to provide the command (less penalty than direct typing on the robot).

1. **Number of Continue's:** Unless stated otherwise, the team leader may request up to two (2) Continue's during a test.
2. **Procedure:** In case a Continue is allowed, the team may request the Continue only at moments in which the robot is failing at carrying out ASR (no pre-emptive Continue's are allowed). A TC member gives the command through the alternative input modality. S/he provides exactly what the user has spoken. The Continue rule will not be allowed, if the robot does not have a keyboard attached or the alternative input modality was not accepted by the TC, or if it is not able to process ASR commands and alternative commands simultaneously.
3. **Time:** The time is neither restarted nor stopped while the Continue rule is applied.
4. **Score:** If one Continue was asked for, the points provided for the ASR part of the test (if any) will be zero and the total points for the test will be multiplied by a factor of 0.5 if the modality of the alternative solution is by typing on a keyboard. To promote other means of interaction, if the modality is different than keyboard typing (i.e. touch interface), the factor to be applied will be 0.75. If two Continues were asked for, the factor will be applied twice.

Alternative methods

Below are some suggested alternatives for ASR:

- Plug in an USB keyboard
- Type in a designed interface in the onboard computer
- A QR code encoding a text is shown to the robot on a laptop screen.
- The robot hosts a website on which some text can be entered.
- A laptop connects to the robot over e.g. ssh where some command can be entered.

3.7. Special penalties and bonuses

3.7.1. 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*.

3.7.2. 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*).

3.7.3. 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.

3.8. Best Test Score Certificate

A certificate will be given to the team with the highest score in each test of Stage 1 and 2.

1. **Requirements:** The score obtained must be at least 70% of the maximum score of the test, excluding:

   1.1. Bonuses for optional tasks.
   1.2. Bonuses for using the smart-house environment.

2. **Special tests:** There is no award for the overall highest score in *Open Challenge* and *RoboZoo*.

Best Test Score Certificate is not given in case the team with the highest score didn't show *sufficient performance* (e.g. trying to score but not solving the task, see Section 3.6.3). The decision about if the award is given is conducted by the *Technical Committee* (TC).

3.9. 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
	$\xrightarrow{advance}$	$\xrightarrow{advance}$	$\xrightarrow{advance}$
	All teams that passed Inspection	Best 10 (< 20) or best 50% (≥ 20)	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 3.6.7). One team after another (and one robot after another) has to enter the arena through a designated entry door, move to a designated intermediate way-point in the arena, and then leave the arena to 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:

    • size of the robot

    • emergency button(s)

    • start button (if the team is going to require it)

    • collision avoidance (a TC member steps in front of the robot)

    • voice of the robot (it must be loud and clear)

    • robot speaker system (plug for RF Transmission)

    • use of external devices (including wireless network)

    • usage of continue rule . The robot must stop anywhere between the entry and exit and wait for someone to say "Continue". Instead of actually saying anything, the team must demonstrate to the TC how to use the continue rule for the robot.

    • other safety issues (cables hanging loose 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):**

   - Specify and announce which doors will be used as entry door and exit door.
   - Specify and announce the location where the robot should drive to in the arena.
   - Specify and announce where and when the poster teaser and the poster presentation session take place.

Chapter 5

Tests in Stage I

*Stage I comprehends four **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. Therefore, the three runs are to be done in direct sequence, i.e. team A goes three times, then team B and so on. This also means that robot should be ready to start the next run of the same test as fast as possible.

RoboZoo (open demonstration for the audience) have no changes from previous years' competitions and is intended to show to an open audience what domestic robots can do. This test grants up to 5 points.

5.1. General Purpose Service Robot

This test evaluates Human-Robot Interaction and the integration of the abilities of the robot tested in stage I. 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 randomly generated by the referees and are composed by 3 subtasks which include navigation, human-robot interaction and robot-object interaction.

The command is composed by three actions, which the robot has to show it has recognized. The robot may repeat the understood command and ask for confirmation. If it can't recognize the command correctly, it can also ask the speaker to repeat the complete command, or ask for further information.

5.1.1. Focus

This test particularly focuses on the following aspects:

- No predefined order of actions to carry out (to get away from state machine-like behavior programming).
- Increased complexity in speech recognition (possible commands are less restricted in both actions/operators and arguments/objects, commands can include multiple objects, e.g., "put the apple on the kitchen table")

5.1.2. Task

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

3. **Command categories:** All possible actions has been classified previously by the TC according to their difficulty level. The team may choose from the following three categories:

   3.1. **Category I:** Tasks with a low degree of difficulty (easy to solve). This category includes indoor navigation, grasping known objects, answering questions (from the predefined set of questions), etc.
   3.2. **Category II:** Tasks with a moderate degree of difficulty. This category includes following a human, indoor navigation in crowded environments, grasping alike objects, find a calling person (waving or shouting), etc.
   3.3. **Category III:** The same tasks as in category II. However, the information given to the robot will be incomplete or incorrect, meaning that the command as it is specified exactly is not possible. The robot must come up with an appropriate solution to meet the operators' command. Please see the Command examples below.

4. **Task assignment:** The robot is given the command by the operator and may directly start to work on the task assignment. The robot must must prove it has understood the given command by repeating it (Please see the remarks about this in section 5.1.4).

5. **Exiting the arena:** After accomplishing the assigned task, the robot has to leave the arena.

5.1.3. Commands and actions

The command is composed by three actions, which the robot has to show it has recognized. The robot may repeat the understood command and ask for confirmation. If it can't recognize the command correctly, it can also ask the speaker to repeat the complete command. If the robot fails to understand the given commands, it may ask to the operator to repeat them up to three times, if it fails the team may opt to use the Continue rule (Section Section 3). In case the robot has understood partially the command, it may ask the operator for additional information (e.g. "did you say apple juice or pineapple juice?").

Required in this test are:

1. abilities from stage I forming a set of actions A (e.g., following a person, finding a random person, finding a person after memorizing her; finding, recognizing, grasping, and delivering objects, etc.),
2. a set of people P,
3. a set of questions Q,
4. a set of objects O (the same set as used as in the other tests),
5. a set of locations L (the same set as used as in the other tests).

Each task assignment contains an action $a \in A$ and, depending on the respective action an object $o \in O$, a location $l \in L$, a question $q \in Q$, a person $p \in P$ to interact with, or a combination of those. The set of actions is not given beforehand, instead, teams should identify the abilities from Stage I by themselves (and find synonyms for that). That is, L, O and Q are known in advance (provided during setup days), but A has to be "found out" by the teams (e.g. taken from freely available ontologies, synonym searches etc.). For the actions A are going to be used common synonyms (like "go to", "move to", "drive to", and "navigate to" to describe navigation). For the people P, any person willing to operate the robot in a natural way can be expected, however, "Professional Operators" are more likely to be used.

Command examples

1. **Category I**

   - Go to the bedroom, find a person and tell the time (there is only one person in the bedroom).
   - Go to the dinner-table, grasp the crackers, and take them to the side-table.
   - Bring a coke to the person in the living room and answer him a question (there is only one person in the bedroom).
   - Go to the door, ask the person there for her name and tell it to me.

2. **Category II**

   - Go to the bedroom, find the waving person and tell the time (there is more than two people in the bedroom, only one waving).
   - Go to the kitchen, find a person and follow her (there is only one person in the kitchen).

- Go to the side-table, grasp the coke, and take it to the dinner table (the way to the bedroom is crowdy and the access to the side-table may be blocked by a human).
- Go to the dinner-table, grasp the banana, and take it to the side-table.

3. **Category III**

   - Take the apple from the sink and carry it to me. (There may no apple in the sink, but maybe another fruit the operator might want, an apple my be found somewhere else, etc.)
   - Go to the kitchen, grasp the coke, and take it to the side-table. (There may no coke in the kitchen but some other drink.)
   - Go to the bathroom, grasp the soap, and take it to the side-table. (The door to the bathroom may be closed. The robot must open the door, find a soap somewhere else or ask someone to open the door for it.)
   - Grasp the fanta from the small table and carry it to me. (When the robot comes back with the drink, I have moved somewhere else and the robot must find me again.)

5.1.4. 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. **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 (Section Section 3.6.11).
   - With the custom operator, the team can only score 50% of the points for the respective command.

3. **Repeating the given command:** The robot must show it has understood the given command by stating all the required information to accomplish the task. This doesn't mean the robot must repeat exactly the same given command. For instance, if the robot is instructed to *"deliver a coke to Mary in the kitchen"*, the robot may ask: *"do you want me to go to the kitchen, find Mary and deliver a coke to her?"* or *"do you want me to find Mary at the kitchen and give her a coke?"* since both sentences involve all given information.

4. **Asking reasonable questions**

   4.1. **Misunderstood information:** When the robot did not understood part of a command or it is unsure of what has been told, it may ask the operator to repeat or clarify without fall into a new attempt. For instance, if the robot is instructed to *"bring me the apple juice from the kitchen table"*, a valid question for the robot to ask is *"did you say apple juice or pineapple juice?"* without considering it as a new attempt for giving the command.

   4.2. **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"*, a proper question for the robot to ask is *"which drink should I deliver to the person at the door?"* It is

also possible that the robot simply confirms the command and fetch a random drink at drinks' location, however, no points will be scored for solving that part.

5. **Following people**

    5.1. **Instruction:** The robot interacts with the operator, *not* the team. That is, the team is not allowed to briefly instruct the operator.

    5.2. **Natural walking:** The operator has to walk "naturally", i.e., move forward facing forward. The operator is not allowed to walk back, stand still, signal the robot or follow some re-calibration procedure.

    5.3. **Asking for passage:** The robot is allowed to (gently) ask people to step aside.

    5.4. **Stopping:** The robot must decide when to stop following a person, either because it was instructed to follow her to a certain location, because it was asked to stop by the operator or because the test time is running out. In any case, the robot should state the reason why it changes its behavior.

5.1.5. Referee and OC instructions

2h before test:

- Specify and announce the entrance and exit door

During the test:

- Generate random sentences by an automatic sentence generator

5.1.6. Score sheet

The maximum time for this test is 6 minutes.

Action	Score
Getting instructions	
Understanding the set of actions on the 1st attempt	*40*
Understanding the set of actions on the 2nd attempt	*20*
Understanding the set of actions on the 3rd attempt	*10*
Reduction of points for every command provided by a team member	*0.5 × -1*
Performing the task: Category I	
Performing the first task correctly	*10*
Performing the second task correctly	*10*
Successfully solving the complete command	*30*
Performing the task: Category II	
Performing the first task correctly	*20*
Performing the second task correctly	*30*
Successfully solving the complete command	*50*
Performing the task: Category III	
Asking reasonable questions to obtain missing information	*20*
Performing the first task correctly	*40*
Performing the second task correctly	*60*
Successfully solving the complete command	*80*
Special penalties & bonuses	
Not attending (see sec. 3.7.1)	*-50*
Outstanding performance (see sec. 3.7.3)	*25*
Total score (excluding penalties and bonuses)	*250*

5.2. Manipulation and object recognition

The robot must reach a bookcase in which there are 10 objects at different shelves in the bookcase. The robot must then identify and grasp and identity 5 of those objects and put those into a new, easy-to-reach shelve that the team/robot may choose.

5.2.1. Goal

The robot has to identify, grasp and correctly place several objects at different heights or positions.

5.2.2. Focus

This test focuses on object detection, and manipulation; as well as object recognition.

5.2.3. Setup

This test may also be held outside the arena. This is in order to have the possibility to run multiple robots in parallel and reduce the total time needed to test all robots.

1. **Location:** One of the bookcases in or around the apartment is used for this test. The robot will start at a random distance between 1.0m and 1.5m from the bookcase. The bookcase has at least 5 shelves between 0.30m and 1.80m from the ground. One of the shelves is empty or will be made empty when the team chooses a shelve.
2. **Objects:** The bookcase contains 10 objects from the Scenario Objects 3.2.5. The robot must grasp 5 objects and identify at least empththose 5 objects.
3. **Object distribution:** The objects are located as follows:
   3.1. Known object in an upper shelf.
   3.2. Known object in a middle shelf.
   3.3. Known object in a lower shelf.
   3.4. Alike object in a middle shelf.
   3.5. Cloth/tray/bowl in a middle shelf

   Optional An occluded or hidden object on a middle shelf (e.g. behind another object or inside a bowl).

   Please note that may be more than one object in each shelf to fit all objects in.

5.2.4. Task

1. **Searching for objects:** When told so by an operator, the robot approaches to the shelf from its nearby starting position and starts searching for objects.
2. **Grasping objects:** Any object found by the robot may be grasped by it. Before or right after grasping the object, the robot has to announce which object it has found.
3. **Placing objects:** After grasping the object, the robot has to safely place it (Section Section 3.2.5) on the empty shelf a the middle of the bookcase. The object must stay there for at least 10sec.
4. **Handling objects multiple times:** Scores can only be gained a single time for each specific object.

5.2.5. 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 3.6.7). If the robot is unable to start it must be removed immediately.
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 shelves or the bookcase 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 3.6.1).
5. **Object types:** The objects selected from the *Standard Objects Set* will be chosen to be easily detectable and contrasting with the shelf (ex. red or black objects on a white shelf).
6. **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 unmistakeable 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 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.

5.2.6. Referee instructions

The referee needs to

- Place the objects in the bookcase
- Make sure there is one empty shelf in the middle of the bookcase. Ask the team which shelve they want to be empty.

5.2.7. Score sheet

The maximum time for this test is 3 minutes.

Action	Score
Grasping objects	
Grasping any object (and successfully lifting it up to at least 5 cm for more than 10 second)	*5 × 10*
Placing objects	
Placing any object (safely and the objects stands still for more than 10 second)	*5 × 10*
Recognizing objects	
Every correctly recognized object in the report file	*5 × 10*
False positive label	*5 × -5*
Hidden object optional	
Finding a hidden or occluded object	*50*
Special penalties & bonuses	
Not attending (see sec. 3.7.1)	*-50*
Outstanding performance (see sec. 3.7.3)	*20*

Total score (excluding penalties and bonuses)	*200*

5.3. Navigation Test

The robot must enter the arena, visit each one from a set of waypoints, and leave the arena. The path from a waypoint to another often blocked by an obstacle that requires the robot to take an action to solve the task.

Actions may include: avoid the obstacle, find a different path, or even interact with the obstacle (move it, open it, ask it to move, wait for it to move, etc.).

5.3.1. Goal

The robot must be able navigate through the apartment, avoiding or interacting obstacles along the way.

5.3.2. Focus

The navigation test focuses on navigating in a changing environment, where doors can be closed and even paths to goal may get blocked by movable temporary objects.

Perceiving the obstacles is also critical in safely navigating a home environment.

5.3.3. Setup

1. **Location:** One of the arenas (apartment). The apartment is in its normal state.
2. **Doors:** All doors in the apartment are open, except for the entry door. The arena will likely contain another door that may be used for this test.

5.3.4. Task

The robot must visit a set of waypoints and avoid the obstacles on its path. Unless stated otherwise, waypoints may be rooms, placement locations, furniture, beacons or landmarks on the floor. The robot must state when it reached a new waypoint.

1. **Entering the arena:** The robot starts outside the environment and must wait until the door opens.
2. **Waypoint 1 (door):** After entering the arena, the robot must navigate to *Waypoint 1*, which may be any location and is reachable via several paths that may include one of more doors. One of the doors may be shut. The robot may:

   - To take a different path.
   - Open the closed door.

3. **Waypoint 2 (obstructed path):** After reaching *Waypoint 1*, the robot must navigate and reach (to grasp distance) *Waypoint 2*, which is a placement location. However, *Waypoint 2* is surrounded by people or movable furniture (e.g. a wheelchair) with which the robot must interact in order to reach its destination. The robot may:

   - Move the obstacle (if the obstacle is an object).
   - Ask the obstacle to move out (if the obstacle is a human).
   - Wait for the object to move away by itself (if the obstacle is another robot).
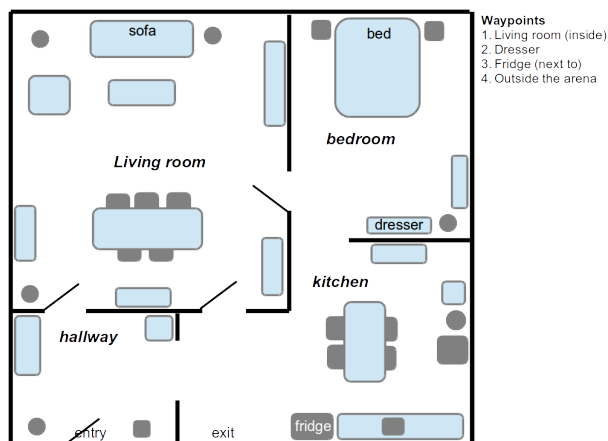
Figure 5.1.: Navigation test: example setup.

4. **Waypoint 3 (following a human):** After reaching *Waypoint 2*, the robot must navigate to *Waypoint 3*, a landmark or beacon. Here is waiting a *Professional Walker* the robot must memorize and follow outside the arena.

   4.1. **Memorizing the operator (training phase):** The robot has to memorize the operator. During this phase, the robot may instruct the operator to follow a certain setup procedure and instruct the operator on what to do when the robot needs to stop following.

   4.2. **Following the operator (guiding phase):** When the robot signals that it is ready to start, the operator starts walking –in a natural way– through a designated path outside the arena. The robot needs to follow the operator until the operator asks the robot to stop doing so (*Waypoint 4*).

5. **Waypoint 4 (going back):** Upon reaching *Waypoint 4*, the *Professional Walker* will command the robot to stop following him, using the instructions given by the robot in the training phase. Then, the robot must navigate back to the starting point (*Waypoint 3*).

6. **Leave the arena:** The robot must leave the arena through the indicated door.

Note 1:   Depending on the layout of the arena, waypoint 1 and 2 may be swapped.

Note 2:   Reaching a waypoint means that the robot is looking at the waypoint-object and that the object is reachable by the robot's arm.

5.3.5. Obstacles

While navigating to waypoints 1 and 2, the robot will find each of the following obstacles on its path:

- **Small object:** Box sized object (between 5 and 15 cm per edge).

- **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.

5.3.6. Additional rules and remarks

1. **Show must go on:** If a robot is unable to reach a waypoint, it must say it and proceed to the next one.
2. **Make it fast:** If a robot is absolutely unable to handle one or more obstacles, please inform the TC before the test so no time is wasted.
3. **Closing doors:** The door that will be shut will be the door on the route the robot has committed to. It will be shut right after the robot starts driving towards the door. The door will be closed well before the robot reaches it so the robot has enough time to notice that the door closed.
4. **Moving objects:** If the robot finds on its way a *static movable obstacle* (chair, cubes, toys, etc.) which is capable to move, it may move the object apart with its manipulator.
5. **When following people:**
   5.1. **Instruction:** The robot interacts with the operator, *not* the team. That is, the team is not allowed to briefly instruct the operator.
   5.2. **Natural walking:** The operator has to walk "naturally", i.e., move forward facing forward. The operator is not allowed to walk back, stand still, signal the robot or follow some re-calibration procedure.
   5.3. **Asking for passage:** The robot is allowed to (gently) ask people to step aside.

5.3.7. Referee instructions

The referee needs to

- Instruct the OC and volunteers on when and where locate objects.
- Instruct the OC and volunteers on when and which doors must be closed.
- Stop the robot immediately when it is about to collide.

5.3.8. OC instructions

2 hours before the test

- Announce the locations for waypoints 1, 2, and 3.

During the test

- Open and close the doors when instructed by the referee.
- Place the obstacles (or act as an obstacle) when instructed by the referee.

5.3.9. Score sheet

The maximum time for this test is 5 minutes.

Action	Score
Waypoint 1	
Opening the door and continue instead of plan a new trajectory	*50*
Reaching waypoint 1	*10*
Waypoint 2	
Detecting and asking a person to step aside	*10*
Moving aside an object to reach the waypoint	*50*
Reaching waypoint 2 (grasp distance)	*10*
Waypoint 3	
Start following the *Professional Walker*	*5*
Reaching again waypoint 3 after reentering the arena (i.e. after reaching waypoint 4)	*20*
Waypoint 4	
Reaching waypoint 4	*15*
Avoiding objects	
Avoiding box-sized object	*10*
Avoiding 3D object (Difficult-to-see object)	*10*
Leaving the arena	
Leaving the arena	*10*
Special penalties & bonuses	
Not attending (see sec. 3.7.1)	*-50*
Outstanding performance (see sec. 3.7.3)	*20*
Total score (excluding penalties and bonuses)	*200*

5.4. Person recognition test

An Operator is introduced to the robot, which needs to learn what the Operator looks like. Once the robot has gathered enough information about the Operator, the Operator mixes within a crowd and the robot needs to find the Operator. Once the robot has found its Operator, it must explain how it must state information about the Operator, such as mood and gender.

5.4.1. Goal

The robot has to identify the Operator within a crowd and state information about the Operator and the crowd.

5.4.2. Focus

This test focuses on people detection and recognition; as well as pose recognition and human-robot interaction with unknown people.

5.4.3. Setup

1. **Operator:** A "professional" operator is selected by the TC to test the robot. This person may a different be drafted from the crowd in each run.
2. **Other people** There are no restrictions on other people walking by or standing around throughout the complete task.

5.4.4. Task

This test may also be held outside the arena This is in order to have the possibility to run multiple robots in parallel and reduce the total time needed to test all robots.

1. **Start:** The robot starts at a designated starting position, and waits for the "professional" operator. When the referees start the time, the team is not allowed to instruct the operator.
2. **Memorizing the operator:** The robot has to memorize the operator. During this phase, the robot may instruct the operator to follow a certain setup procedure. **Learning operator name:** Optionally, the robot may ask the operator for his/her name and make the interaction after finding the operator again more natural.
3. **Wait for Start Command:** Once the robot states it has finished memorizing the operator, it must wait for a Start Command via ASR (or using the Continue rule if need be; Section Section 3) while the operator walks around the robot and moves behind it to blend in with the crowd. This test is not concerned with audio and voice recognition. Therefore, the start command may also be given by a single key press.
4. **Find the crowd:** After the time elapses, the robot must turn about 180°, approach to the crowd and start looking for the operator.

   - **Crowd size:** The crowd may contain between 5 and 10 people, standing or sitting or lying within an area of 5 meters (diameter).
   - **Crowd position:** The crowd will be located behind the robot at a distance between 2 and 3 meters apart.

5. **Find the operator:** Once the crowd has been located, the robot must greet the operator (optionally by name) and state the gender, and pose (sitting, standing, rising arms, etc.). Also, it must point or approach to the operator. In any case, it must be clear to the referee that the robot has found the operator, unambiguously. If this is not the case, no points will be scored.

   For example: when the robot says *I found you operator, you are the smiling girl sitting in the middle of the crowd.* In the case of two smiling girls in the middle of a four person crowd, there is ambiguity and thus no points.

6. **Describe the crowd**: Finally, robot must tell the size of the crowd and how many men, women and even children are.

5.4.5. Additional rules and remarks

1. **Preparation:** The robot needs to wait for at least 1 min before the operator appears in front of the robot. During this waiting time the team is not allowed to touch the robot.

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

3. **Instruction:** The robot interacts with the operator, not the team. That is, the team is not allowed to instruct the operator.

5.4.6. OC instructions

2 hours before the test

- Select the "professional" operator(s).
- Select the crowd.

During the test

- Check safe operation of the robot; the robot needs to be stopped immediately if a person is going to be touched by the robot

5.4.7. Score sheet

The maximum time for this test is 5 minutes.

Action	Score
Operator	
Approach or point at the operator	*30*
Correctly state operator's gender	*30*
Correctly state operator's pose	*30*
Correctly state crowd's size	*20*
Correctly state crowd's number of men	*20*
Correctly state crowd's number of women	*20*
Special penalties & bonuses	
Not attending (see sec. 3.7.1)	*-50*
Outstanding performance (see sec. 3.7.3)	*15*
Total score (excluding penalties and bonuses)	*150*

5.5. RoboZoo

The robots of all teams are presented and arranged in a way that all of them form a zoo-type corridor through which the general audience will walk. Each robot is enclosed within a space that it cannot get out of, and it must perform a show for up to one hour, such as dancing or carrying out any menial task. Each member of the audience who enters the corridor will receive 5 tokens which will be given to his/her top 5 favorite robots. The robot who earns the most tokens wins the contest and gets the maximum score. Points are awarded to the other robots based on the amount of tokens they gathered, proportional to the amount of tokens gotten by the robot that won the contest.

Interaction with the audience is desirable but not mandatory.

5.5.1. Enclosed Space Dimension

The enclosed space is estimated to be around 2×2 meters. However, teams should expect reasonable deviations in these dimensions, since space in the venue may require smaller enclosed spaces.

5.5.2. Security Concerns

Security is first priority in this competition. To this effect, one team member is required to be inside the enclosed space to ensure that the robot is performing securely. Physical interaction between audience members and the robot is not allowed (i.e. robot handing things to people or shaking hands). Interactions such as talking to the robot, or carrying out face recognition are allowed. To not limit the creativity of the teams in their demonstrations, the robot may hand-out items to the public via using the one team member inside the enclosed space as a type of proxy. In addition, persons from the general public are not allowed inside the enclosed space at any moment.

Important Note: Even if people is not allowed to enter the robots' cages, it may happen people (specially small children) get into the cages. In those cases, robot must be shut down immediately.

5.5.3. Restart and Charging

If the robot requires a restart, the one team member inside the enclosed space may tend to it and restart it as much times as required. However, it is important to note that this test is essentially scored by the general public, and it is reasonable to expect that the audience will not be attracted to a robot being constantly fixed. In addition, since this test may last up to one hour, the robot may require a change of batteries or to use a charging station, which is allowed. However, as pointed out before, this may not be attractive to the audience, so it is recommended to reduce the charging necessities to a minimum.

5.5.4. Additional rules and remarks

- **Gifts:** Robots and team member are *not* allowed to hand out gifts as part of the RoboZoo challenge.

- **Protagonist robots:** Robots must be able to perform autonomously during the test. Team members are *not* allowed to interact with the audience, teach instructions, take part of the show, etc. In the case that team members are lurking around the cages or interacting with the audience, that team will be disqualified.
- **People in the cage:** At any time, one team member must be inside the cage to take care of the robot. More than one team member inside the cage is *not* allowed.

5.5.5. OC instructions

2h before test:

- Announce to teams the dimension of the enclosed spaces.
- Specify where the presentation will take place.
- Specify which space will be occupied by which robot.

5.5.6. Score Sheet

The maximum time for this test is 60 minutes.

Robots are scored on functionality and on design. The audience can awards tokens for what they elect to be the **Most functional robot** and the **Best looking robot**.

Action		Score
Appearance	$25 \times \frac{this}{best}$	
Performance	$25 \times \frac{this}{best}$	
Special penalties & bonuses		
Not attending (see sec. 3.7.1)		*-50*
Outstanding performance (see sec. 3.7.3)		*5*

Total score (excluding penalties and bonuses)   *50*

Normalization: The teams with less tokens than the best team get proportional score based on the number of tokens they received, e.g score for this team $= 25 \times \frac{t_{this}}{t_{best}}$ where t_{this}, t_{best} is the number of tokens received by this team, and the number of tokens received by the best team.

5.6. Speech Recognition & Audio Detection Test

This test is divided in two phases. First the robot must answer a set of questions to an operator at the first attempt without asking for confirmation. The operator is not allowed to move to the robot or shout to the robot.

For the second phase, the Operator will move behind the robot and ask a set of questions which the robot must answer. The robot is allowed to turn to the operator and ask it to repeat the question, and the operator will repeat the question only once before moving again behind the robot and proceed with the next question.

5.6.1. Goal

The robot must be able to properly recognize and answer to a specific set of questions without ask for confirmation. Also, the robot shall be able to react to a speaking operator which is not facing to it.

5.6.2. Focus

This test focuses on voice recognition and audio-source localization in a noisy environment, with moving sound sources[1].

5.6.3. Setup

1. The apartment is in its normal state.
2. All doors of the apartment are open, except for the entry door.

5.6.4. Task

1. **Direct speech recognition:** The robot should move (or be moved) to a previously specified point inside the arena. A TC member will ask 5 questions from the set of 50 predefined questions in front of the robot. The robot should answer the question without asking confirmation. A question will only be asked once; there are no repetitions of a question.

   - The operator shall be standing still and facing to the robot.
   - The operator shall be between 0.75 and 1.0 meters away from the robot position.
   - The operator shall be between -60° and 60° from the robot's center (front range).

2. **Indirect speech recognition:** A TC member will ask another 5 question of the same set, but standing outside the front range of the robot at the same distance. The robot can do one of two things (each providing different amount of points):

   - The robot may turn its microphone towards the operator and ask for only one repetition of the question. The robot should then answer without asking for confirmation.
   - The robot may directly answer the question without turning towards the operator and without asking for confirmation.

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

5.6.5. Additional rules and remarks

- **Continue rule:** Continue rule (Section Section 3) can not be used during this test.
- **Question timeout:** If the robot does not answer within 10 seconds, the question is considered as *missed*, and the TC member will proceed with the next question.
- **Understanding the answer:** If the robot's answer is not understood by the operator, it is considered as *incorrect*, and the TC member will proceed with the next question. It is thus advised that the robot provide answers such that it is clear that the robot understood the question. For example, if the question is "What is the capital of Germany?", instead of just answering "Berlin", it is advised that the robot answers something to the effect of "The capital of Germany is Berlin".
- **Question repetition:** In the second phase, if the robot turns towards the operator to be asked once again, it should clearly state that it requires a repetition of the question once it finishes turning, so as to queue the operator to do so.

5.6.6. Referee instructions

The referee needs to

- Avoid shouting to the robot.
- Avoid getting closer to the robot.
- Speak to the robot loud and clear with plain standard English.
- Avoid repeating questions for the same robot.

5.6.7. OC instructions

1 day before the test

- Provide the set of 50 predefined questions

2 hours before the test

- Announce the placement of the robots

5.6.8. Score sheet

The maximum time for this test is 5 minutes.

Action	Score
Operator within the front range	
Correctly answered question 1	*10*
Correctly answered question 2	*10*
Correctly answered question 3	*10*
Correctly answered question 4	*10*
Correctly answered question 5	*10*
Operator outside the front range 2nd *attempt after asking operator to repeat the question*	
Correctly answered question 1 (1st attempt)	*20*
Correctly answered question 1 (2nd attempt)	*10*
Correctly answered question 2 (1st attempt)	*20*
Correctly answered question 2 (2nd attempt)	*10*
Correctly answered question 3 (1st attempt)	*20*
Correctly answered question 3 (2nd attempt)	*10*
Correctly answered question 4 (1st attempt)	*20*
Correctly answered question 4 (2nd attempt)	*10*
Correctly answered question 5 (1st attempt)	*20*
Correctly answered question 5 (2nd attempt)	*10*
Special penalties & bonuses	
Not attending (see sec. 3.7.1)	*-50*
Outstanding performance (see sec. 3.7.3)	*15*
Total score (excluding penalties and bonuses)	*150*

Chapter 6

Tests in Stage II

All ability and integration tests in Stage II grants 250 points (but the Open Challenge which grants 200) and are performed only once. Some tests –like Wake-me-up Test– 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. Open Challenge

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

6.2.1. Task

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

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

6.2.2. Presentation

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

- A video projector or screen, if available, may be used to present a brief introduction.
- The team can also visualize robot's internals, e.g., percepts.

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

6.2.3. Changes to the environment

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

6.2.4. Jury evaluation

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

   2.1. Overall demonstration
   2.2. Human-robot interaction in the demonstration
   2.3. Robot autonomy in the demonstration
   2.4. Realism and *usefulness for daily life* (Can this robot become a product?)

2.5. Novelty and (scientific) contribution (+contribution to the community)

2.6. Difficulty and success of the demonstration

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

3. Normalization and outliers:

3.1. The points given by each jury member are scaled to obtain a maximum of *250 points* (i.e., multiplied by $25/6$).

3.2. The total score for each team is the mean of the jury member scores. To neglect outliers, the N best and worst scores are left out:

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

6.2.5. Additional rules and remarks

1. **Start signal:** There is no standard start-signal for this test.

2. **Abort on request:** At any time during the demonstration, the jury may interrupt and abort the demonstration:

   2.1. if nothing is shown: in case of longer delays (more than one minute), e.g., when the robot does not start or when it got stuck;

   2.2. if nothing new is shown: the demonstrated abilities were already shown in previous tests (to avoid dull demonstrations and push teams to present novel ideas).

3. **Team-team-interaction:** An extra bonus of up to 5 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.

6.3. Restaurant

The robot is tested in a real environment such as a real restaurant or a shopping mall.

6.3.1. Focus

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

The robot will need to create its own map from the environment and then move into it to handle human requests, such as delivering drinks or snacks, while people are walking around.

6.3.2. Setup

1. **Location:** A real restaurant fully equipped with a "Professional Waiter" and at least three tables with "Professional Clients".

6.3.3. Task

1. **Instruction:** In case the robot can work with a "Professional Waiter", the team should very briefly instruct the waiter how to command the robot, e.g. what to say when a table location must be memorized etc.
2. **Start:** The robot starts at a designated starting position, and waits for the "Professional" operator. When the referees start the time, the team is allowed to (briefly) instruct the operator. After the instruction, the operator steps in front of the robot and tells it to follow (no start signal).
3. **Memorizing the operator:** The robot has to memorize the operator. During this phase, the robot may instruct the operator to follow a certain setup procedure.
4. **Guide phase:** Starting from the *Kitchen*, the robot is guided through the environment by a "Professional Waiter" which shows to the robot the location of each of the tables, its number, and on which side the table is (there is a total of 3 tables). After visiting all the tables, the robot must be guided again to the *Kitchen*, to the same place where the guide phase started.

   - **Own *Professional Waiter* [Optional]:** Team Leader may choose to use their own custom *Professional Waiter* for this test instead of the one provided by the committee. The Team Leader must inform a TC member at least one hour before the competition. When using a custom *Professional Waiter*, no points are earned for state the side of the table.
   - **Finding the tables [Optional]:** Team Leader may choose not to tell the robot on which side (left or right) is the table, and let the robot find the tables by itself. When using this option, the robot must state where the table is (i.e. by telling: *the table is to my right*).

5. **Ordering phase:**
   5.1. **Which table to attend:** Once back in the kitchen, the robot shall ask to the *Professional Waiter* to which table go first to take an order from. The robot has to go to the indicated table and ask for an order there. This interaction of telling the

robot which table to attend should be natural. Just saying "1" to the robot is not natural, you would not say this to a person either who has to attend table 1.

5.2. **First order (Table A)**: The robot must aks the person what he or she wants to order. See Orders below for details about ordering.

5.3. **Detecting a call (Table B or C):** At any time while attending Table A's guests (going to fetch an order, asking the client, or returning to the kitchen with the order), a guest at Table B or C 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 and that it will attend as soon as possible. If the robot does not detect such a call, it may be given a command to go to the next table when it is back at the kitchen after finishing table A's order.

5.4. **Second order (Table B or C):** After taking the Table A client's order, and if the request was detected, the robot must go to the table of the waving/calling person and ask for an order.

5.5. **Avoiding random citizen:** 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 the robot to avoid that person or stop and wait for it to move away.

Orders: The menu offers Beverages and Combos. An order may be a Beverage or Combo. One guest will order a Combo while the other 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 their would in a restaurant operated by humans.

Note: Table A, B and C may be any of Table 1, 2, 3, . . . , N in any order.

6. **Delivering phase:**

6.1. **Repeating the order:** Once again in the kitchen, the robot recites the orders for each table, including the table number (e.g. *Hamburger with fries for table 1 and Orange juice for table 2*), to the *Professional Barman*. This includes determining the table number of the waving/calling person. 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.

6.2. **Delivering Beverage:** The robot must grab a can of the appropriate drink from a set of cans on the Kitchen-bar and deliver it to the correct table.

6.3. **Delivering Combo:** The robot must carry a tray with the ordering to the table the food was ordered from. 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.

7. **Next customer, please:** The task is finished when the robot has delivered both orders and is back at the kitchen.

6.3.4. Additional rules and remarks

- **Safety!** This test takes place in a public area. That is, there may be people standing, sitting or walking around the area throughout the test. The robot is expected to not even
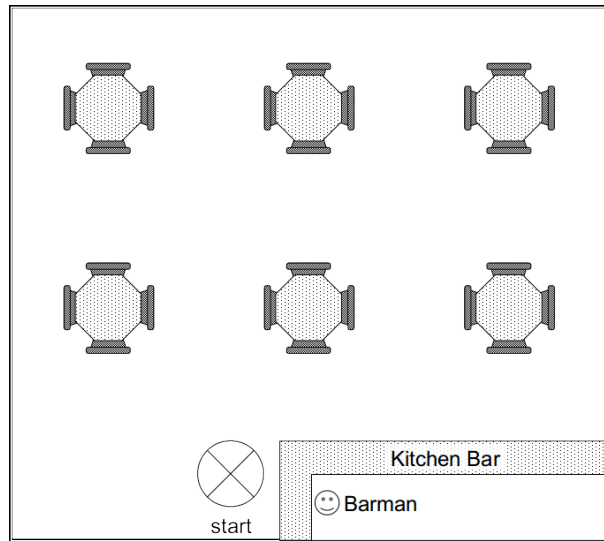
Figure 6.1.: Restaurant test: example setup.

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.
- **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).
- **Natural walking:** The operator has to walk "naturally", i.e., move forward facing forward. If not mentioned otherwise, the operator is not allowed to walk back, stand still, signal the robot or follow some recalibration procedure.
- **Disturbances from outside:** If a person from the audience (severely) interferes with the robot in a way that makes it impossible to solve the task, the team may repeat the test immediately.
- **Learning tables:** Of course, it can only be sure that a robot correctly learned a table when it is able to go there after being commanded so.
- **Instruction:** The robot interacts with the operators, not the team. That is, the team is only allowed to (very!) briefly instruct the *Professional Waiter* and *Professional Barman*

  - how to the tell the robot to follow,
  - how to visually/acoustically indicate table names and position (e.g., pointing or telling "Table 1 is on your left"),
  - how to the tell the robot the *Guide Phase* has ended, and
  - 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 *Guide Phase* started and ended. 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 the beginning or the end of the guide phase. It has the following setup.

  - **Barman:** A *Professional Barman* (member of the TC) will be at the other side of the Kitchen-bar to take the order provided by the robot and serve it in the official tray.
  - **Beverages:** Beverages will be located on the Kitchen-bar next to the *Professional Barman*.

6.3.5. Score sheet

The maximum time for this test is 10 minutes.

Action	Score
Training phase	
Learning the location of a table (Professional Waiter)	*3 × 10*
Learning the location of a table (Custom Waiter)	*3 × 5*
Inferring the side on which a table is (Professional Waiter only)	*3 × 10*
Ordering phase	
Understanding which table to take an order from	*5*
Going to the designated table	*15*
Taking an order from the designated table	*10*
Noticing a waving/calling person from distance	*20*
Going to the table of the waving/calling person	*20*
Taking an order from the waving/calling person	*10*
Avoiding a person crossing the robots' path	*10*
Delivering phase	
Reciting both the order and table number for both tables	*2 × 5*
Grasping the correct drink	*10*
Getting close to the correct table with the drink	*15*
Delivering the drink by placing it on the correct table	*15*
Picking up the plate	*15*
Getting close to the correct table with the plate	*15*
Delivering the plate by placing it on the correct table	*20*
Special penalties & bonuses	
Not attending (see sec. 3.7.1)	*-50*
Outstanding performance (see sec. 3.7.3)	*25*

Total score (excluding penalties and bonuses)	*250*

6.4. Robo-Nurse

The robot is assisting an elderly person with getting her pills and responding to observed activities.

6.4.1. Focus

This test focuses mainly on Human-Robot Interaction and Activity Recognition.

6.4.2. Task

1. **Start**: The robot is in a corner of the living room; the patient is sitting in the same room.
2. **Move to the patient**: The patient (lets call her Granny) calls for robot assistance using her voice or by waving arms.
3. **Asking for pills**: Granny asks the robot for her pills which are in bottles located on a shelf nearby. This is the start command for the robot and may be defined by the team. Because this test is an integrated scenario, the command should make sense in the context fo the test. For example "Continue" does not make sense but "I need my pills, robot" and "Robot, please get me my pills" do make sense. The team must instruct "granny" about what to say.
4. **Describe and choose pills**: On the shelf, there are multiple bottles with pills and the robot must asks Granny which bottle she needs.

   - The robot must indicate what bottles are on the shelf by briefly describing each bottle. **the faster the robot starts describing (i.e. finished recognizing) after arrival (standing still in front of the shelf) at the shelf, the better:** faster recognition gives more points. For scoring, the time between the robot's arrival and the start of speaking the description is taken.
     - "The leftmost one"
     - "The *color* bottle"
     - "The big/small bottle"
     - Any other description the robot understands and spoke out loud to Granny. E.g. if a robot can do text recognition and read each label to Granny, she may reply with e.g. "Aspirin".
   - The bottles will be previously unseen by the robots and thus cannot be trained. The descriptions thus have to really be created from observations, on the fly.

5. **Grasp & handover pills**: The robot must grasp the indicated bottle of pills and hand it over to Granny. The handover to Granny must be "natural", without a voice confirmation of when to let the pills go etc. Granny will take the pills from the robot's hand and the robot must open its hand.
6. **Open pills bottle [Optional]:** After grasping a pills bottle, the robot may try to open it before delivering it to Granny.
7. **Give a single pill [Optional]:** If the robot succeeds opening the pills bottle, it may try to fetch a single pill from it to delivery to Granny.
8. **Activity Recognition**: One of the activities below happens and the robot must act accordingly:

   - **Drop blanket**: Granny's stands up and sits down immediately. Her blanket falls from her lap to the ground. The robot must **pick up the blanket** and hand it to Granny.
   - **Fall**: Granny stands up from her chair and falls. The robot must **hand Granny a phone**. The phone will be laying nearby, e.g. on the coffee table in the living room.
     [Optional]: Robot may use Smart House option to do a phone call instead of delivering the phone to Granny.
   - **Walk and sit**: Granny walks to a table with her walking stick/cane. Robot must follow her and take the walking stick from Granny after she sits down on a nearby chair.

6.4.3. Additional rules and remarks

1. **Calling for assistance:** Points will only be scored for attention calling when the robot directly responds to the waving or voice calls. Responding in this case means starting to move toward Granny or the robot should say it detected a call etc. In any case, it should be clear to the referee that the robot detected the action.
2. **Continue Rule:** The CONTINUE rule may be applied several times in the Conversation part of the test (Section Section 3).
3. **Make it fast:** Description of objects should be fast, as is reflected in the scoring.
4. **Opening pill bottles:** Provided pills' bottles will be chosen so they can be opened easily by twist, i.e. no push and twist, no uncap, no seals nor any other complex opening method.
5. **Optional tasks:** The test includes optional tasks (such as describe unknown objects, opening bottles, and grasping very small objects) which are not required to be performed as part of the overall test but brings an additional scoring for solving it. Team leader must contact a TC member to request optional tasks to be available.
6. **Smart-house:** The arena-house may have enabled official smart-house devices (Section Section 3.2.10), there are additional scoring for interacting with the house.

6.4.4. Referee instructions

The referee needs to

- Place the pill bottles on the shelf.
- Place the phone on announced position.

6.4.5. OC instructions

2 hours before the test

- Announce the room where the patient is.
- Find at least 5 items that can serve as pill bottles.
- Announce the room where the phone is.

During the test

- Instruct Granny which pills she wants.
- Instruct Granny which of the 3 actions to perform.

6.4.6. Score sheet

The maximum time for this test is 10 minutes.

Action	Score
Attending request	
Reach patient after being called	*20*
Await command to get pills	*10*
Describing pills	
Real time description (given upon arrival)	*50*
Description given within $t \leq 5$ seconds	*30*
Description given within $5 < t \leq 15$ seconds	*20*
Description given within $15 < t \leq 30$ seconds	*10*
Description given within $t \geq 30$ seconds	*00*
Picking pills	
Choose the correct pills	*40*
Grasp the correct pills	*20*
Grasp wrong pills	*5*
Pills handover	
Natural delivery (no instructions are given to operator)	*20*
Assisted delivery (operator instructs robot for delivery)	*10*
Activity recognition	
Granny trying to reach drop blanket	*50*
Falling Granny	*50*
Granny stands up and walk away + sit	*50*
Response to activity	
Pickup the blanket + give the blanket	*40*
Grasp phone + give phone	*40*
Take walking stick / cane	*40*
Bonuses (up to 180 points)	
Using Smart House to call instead of grasping & giving the phone	*10*
Describe unknown pills' bottles	*30*
Opening the pill bottle (with a screw cap)	*40*
Picking a single pill from the bottle	*100*
Special penalties & bonuses	
Not attending (see sec. 3.7.1)	*-50*
Outstanding performance (see sec. 3.7.3)	*25*
Total score (excluding penalties and bonuses)	*250*

6.5. Wake me up test

The robot's owner has overslept. Knowing the schedule of the owner and noticing it is getting late, the robot helps its owner to wake up and start the day.

The robot has to help a human in a daily morning task. The task involves interact with a smart house, awake a dormant human, take an order, prepare the breakfast and deliver it to the human.

6.5.1. Focus

This test focuses on advanced object manipulation, human pose detection, object recognition and and manipulation; as well as object recognition.

6.5.2. Task

1. **Awakening the owner:** The robot enters the bedroom, approaches to the bed, and starts to awaken the owner (operator lying on the bed) for one minute by playing an alarm-like sound or using its own voice. Within one minute starting from the first call, the owner will wake up in a natural way (sit on the bed and rub face; sit on bed, rise arms and yawn; stand up etc.), then the robot must announce it has successfully detected the awakening by greeting it's owner. The robot should respond to the awakening directly, otherwise no points will be awarded.

   - **Turning-on bedroom's lights [Smart-house option]:** After entering to the bedroom, the robot can send a command to the house to turn on the bedroom lights.
   - **No annoying sounds:** Alarm-like sounds must be short and clean (no continuous music is allowed), and voice calls must be short and clear. A silence gap of 10 seconds between calls is advised.
   - **Show must go on:** One minute after the first call, the owner is awake, so the robot must proceed to the next point.

2. **Delivering the newspaper [Optional]:** After awakening its owner, the robot approaches to her and delivers a newspaper into the owner's hand (the owner will face the robot after being awakened and extend her hand to it). Robot must release the newspaper only after the human has grasped it.

3. **Taking breakfast order:** The robot asks to its owner for a breakfast of her preference. The order will include: one random fruit/snack, one kind of cereal, and one kind of milk (stating no milk means whole milk), but those can be given in any order. The robot may ask for a confirmation of the order up to three times. If the robot is not able to handle a tray (see below), it must state that breakfast will be delivered to the dining room. Examples of the order are:

   - Froot-Loops with banana and light milk.
   - Flakes with lactose-free milk and a peach.
   - Apple and choco-flakes (i.e. one apple, and choco-flakes with whole milk).

4. **Opening kitchen's door [Optional]:** The kitchen's door is closed. Upon arrival, robot may try to open the door. The robot may also give up and request for the door to be opened by a referee. If the robot succeed on opening the door, the jury may add up to 5 minutes to the time for completing the test.

5. **Turning-on kitchen light [Smart-house option]:** After entering to the kitchen, the robot can send a command to the house to turn on the kitchen lights and the coffee brewer. Kitchen lights must be turned on every time the robot enters the kitchen.

6. **Serving the breakfast:** Once in the kitchen, the robot must locate the tray and place into it the requested fruit/snack, a box of the requested type of milk, and a bowl; then pour the requested type of cereal into the bowl. If the robot is not capable of handling a tray, it may serve the

breakfast directly at the diner table. The placement order is not relevant, nor is the serving order. An example is provided below:

- **Find tray:** The robot locates the tray in the table and pulls it to make easier placing objects.
- **Place milk:** The robot locates the requested type of milk (whole) among many (whole, light, lactose-free) in the shelf, and places it on the tray at the top-right corner.
- **Place fruit:** The robot locates the requested type of fruit (apple) among many (apple, banana, apricot) in the table, and places it on the tray at the top-left corner.
- **Place bowl:** The robot locates the bowl in the table and places it on the tray at the middle.
- **Pour cereal:** The robot locates the requested type of cereal (flakes) among many (choco-flakes, flakes, Froot-Loops) in the shelf, grasps the box, pours the cereal it into the bowl and puts the cereal box back into the shelve.

7. **Placing the spoon [Optional]:** After placing the cereal bowl on the tray or dining room table, the robot may place a spoon close to it. Delivering the tray: After placing objects into the tray, the robot must take the tray and deliver it to the human in the bedroom, leaving it on a table or directly to the owner's hands.
8. **Turning-off kitchen light [Smart-house option]:** After leaving to the kitchen, the robot can send a command to the house to turn off the kitchen lights. Kitchen lights must be turned off every time the robot leaves the kitchen.
9. **Doing the bed [Optional]:** After the breakfast has been delivered, the robot may proceed to do the owner's bed. Points may be awarded based on TC & *Professional Mom* criteria. If the robot succeed on doing the bed, the jury may add up to 5 minutes to the time for completing the test.

6.5.3. Additional rules and remarks

- **Bowl and tray:** Both, the bowl and tray are taken from the official containers list (see Section 3.2.5) and known beforehand. The bowl will be used to pour cereal inside (only cereal, not milk) and the tray to transport the bowl, milk and fruit. Containers will be placed on a flat surface for convenience.
- **Breakfast objects:** The milk and cereal boxes will be taken from the known objects list, and the fruit from the alike objects list (see Section 3.2.5). There will be more than one milk, cereal and fruit, so the robot will need to pick the proper one. Objects will be placed close in order to minimize the required navigation time for the robot.
- **Collaborative test:** The team leader may request help from a second team to perform the "serving the breakfast", "delivering the tray" tasks, and "smart-house" optional. All score achieved by both robots is given to the main team, but also the points scored by the helping-robot are given to the helping team as a bonus. This cooperation must be informed to the TC at least two hours before the competition.
- **Fruit or snack?:** If the robot is not able to properly handle fruits (alike objects), it can be replaced by easier-to-manipulate objects from the known objects list. Team leader must contact a TC member to request using snacks (known objects) instead of fruits (alike objects, see Section 3.2.5).
- **Newspaper:** The Newspaper is provided to the Team Leader by the OC before the robot enters the arena holding the newspaper. The Team Leader must bring the Newspaper back to the OC before the end of the test.
- **Optional tasks:** The test includes optional tasks (such as deliver the newspaper, placing the spoon, and doing bed) which are not required to be performed as part of the overall test but brings an additional scoring for solving it. Team leader must contact a TC member to request optional tasks to be available.
- **Pouring the cereal:** In case the robot is not able to pour inside the bowl, it may just handle cereal box, either into the tray or to the table.
- **Smart-house:** The arena-house may have enabled official smart-house devices (Section Sec-

tion 3.2.10), there are additional scoring for interacting with the house.
- **Doing the bed:** Additional points may be awarded by the TC to the team whose robot succeed in doing the bed. The TC decision involve the following aspects:
    - **Bed:** A bonus of +2 points for covering the bed sheet with blanket/duvet. An additional bonus of +3 points may be given by the *Professional Mom* for a neat appearance (e.g. no wrinkles or bearings in the bed sheet and blanket/duvet).
    - **Pillow:** A bonus of +2 points for positioning the pillow in the header of the bed. An additional bonus of +3 points may be given by the *Professional Mom* for correct placement and neat appearance(e.g. correctly placed at the middle of the bed with the proper tilt).

Notice that the uses and customs of the host country apply for dimensions and linen for both, bed and pillows. Hence, there is no predefined way for doing bed and robot must adapt to the provided ones. For scoring purposes, the TC may require locals' opinion (i.e. a *Professional Mom*) to check if the bed has been properly done.

6.5.4. Referee instructions

The referee needs to

- Give a wake-up signal to the operator within a minute, starting when the robot begins to try to awake the operator.
- Generate and provide a random breakfast order for the operator
- Type the breakfast order in a qualified typing device when required (Continue rule, Section Section 3).
- Stop the robot immediately when tray is about to fall

6.5.5. OC instructions

2 hours before the test

- Announce the placement of the objects (Cereal, milk, and fruit).
- Announce the placement of the containers (tray and bowl).
- Announce the default breakfast objects.

During the test

- Provide teams with the newspaper
- Place tray and breakfast objects into the kitchen
- Place spoon when needed

6.5.6. Score sheet

The maximum time for this test is 10 minutes.

Action	Score
Awakening the human	
Detect the human awakening	*20*
Taking the order	
Understanding whole order	*20*
Understanding whole order on console (typed)	*5*
Robot's own suggestion for breakfast	*00*
Serving breakfast	
Placing the bowl	*20*
Placing the milk bottle ($\frac{1}{2}$ score on wrong milk type)	*10*
Placing the fruit/snack ($\frac{1}{2}$ score if using snack instead of fruit, $\frac{1}{2}$ score on wrong object type)	*20*
Pouring cereal into the bowl ($\frac{1}{2}$ score on wrong cereal type)	*30*
Spilling cereal outside the bowl	*-10*
Spilling much cereal outside the bowl	*-20*
Delivering breakfast	
Grasping the tray (and successfully lifting it up to at least 5 cm for more than 10 second)	*30*
Safely transporting the tray (no object inside flipped or fell during transport)	*10*
Placing the tray (safely and the tray stands still for more than 10 second)	*20*
Handing-over the tray to the operator's hands	*40*
Complete the task with complete and correct order	*20*
Smart-House optional	
Turning on bedroom lights on enter	*10*
Turning on kitchen lights and coffee brewer on enter	*10*
Turning off kitchen lights on leave	*10*
Optional tasks (up to 200 points)	
Handing-over the newspaper	*20*
Opening kitchen's door	*50*
Placing the spoon	*30*
Doing bed	*100*
Special penalties & bonuses	
Not attending (see sec. 3.7.1)	*-50*
Outstanding performance (see sec. 3.7.3)	*25*
Total score (excluding penalties and bonuses)	*250*

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

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 3.5.5. 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.

A.1. Skills by category

A.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.

A.1.2. Complex vision

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

A.1.3. Complex navigation

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

A.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 vocubulary.
- 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).

A.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).
-

A.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.

Abbreviations

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