



RoboCup@Home

Rules & Regulations

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About this rulebook

This is the official rulebook of the RoboCup@Home competition 2014. It has been written by the 2013/2014 RoboCup@Home Technical Committee (in alphabetical order): Kai Chen, Dirk Holz, Caleb Rascon, Javier Ruiz des Solar, Amirhosein Shantia, Komei Sugiura, Jörg Stückler, and Sven Wachsmuth.

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Chapter 1

Introduction

1.1 RoboCup

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

1.2 RoboCup@Home

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

1.3 Organization

1.3.1 Executive Committee — ec@robocupathome.org

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

- Dirk Holz (University of Bonn, Germany)
- Javier Ruiz del Solar (Department of Electric Engineering, Universidad de Chile, Chile)
- Komei Sugiura (National Institute of Information and Communications Technology (NICT), Japan)
- 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 2013:

- Kai Chen (University of Science and Technology of China, China)
- Caleb Rascon (Universidad Nacional Autnoma de México, Mexico)
- Amirhosein Shantia (University of Groningen, The Netherlands)
- Jörg Stückler (University of Bonn, Germany)

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 2013:

- **Chair:** Maja Rudinac (Delft University of Technology, The Netherlands)
- **Local Chair:** Josemar Rodrigues de Souza (Bahia State University, Brazil)
- Rong Xiong (Zhejiang University, China)
- Pruittikorn Smithmaitrie (Prince of Songkhla University, Thailand)
- Mauricio Matamoros (Universidad Nacional Autnoma de México, Mexico)
- 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
robocup-athome@lists.robocup.org

You can register to the email list at:

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

1.4.2 RoboCup@Home Web Page

The official *RoboCup@Home website* that also hosts this rulebook can be found at
<http://www.robocupathome.org/>

1.4.3 RoboCup@Home Wiki

The official *RoboCup@Home Wiki* is meant to be a central place to collect information on all topics related to the RoboCup@Home league. It was set up to simplify and unify the exchange of relevant information. This includes but is certainly not limited to hardware, software, media, data, and alike. The *wiki* can be reached at

<http://robocup.rwth-aachen.de/athomewiki>.

To contribute, i.e. to add/edit/change things you need to create an account and log in.

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 honor 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 Technical Challenge

In parallel to the regular competition, the RoboCup@Home league features a technical challenge. The winner of the technical challenge is given a special *award for winning the technical challenge*.

As with the innovation award, the award for winning the technical challenge is not given in case no team shows a *sufficient performance*. The decision which team wins the technical challenge, and if the award is given at all, is conducted by the Technical Committee (TC).

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 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 and the referees on site.

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. Since 2007 there is also the *RoboCup@Home Wiki* (see 1.4.3) which serves as a central place to collect information relevant for the @Home league. Every team is expected to share relevant technical, scientific (and team related) information there and in its *team description paper* (see 3.1.4).

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*. As a minimum requirement for qualification, we consider showing the robot(s) successfully solving at least one test of the current or last year’s rulebook.

3.1.3 Team Website

The *Team Website* has to contain photos and videos of the robot(s), a description of the approaches, and information on scientific achievements, relevant *publications*, team members, and previous participation in RoboCup.

The information on the team website has to be in English and should be designed for a broader audience.

3.1.4 Team Description Paper

The *team description paper* (TDP) should at least contain the following sections:

- Name of the team
- contact information
- website
- team members
- description of the hardware, including photo(s) of the robot(s)
- description of the software

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

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.

3.1.5 Qualification

During the *qualification process* a selection will be made by the organizing committee. Taken into account and evaluated in this decision process are:

- The information on the team website and the qualification video,
- the information in the *team description paper*, and
- the information in the *RoboCup@Home Wiki* (added by the team).

(Additional) evaluation criteria are:

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

For getting considered in the evaluation, be sure to insert your team's name when adding information to the *RoboCup@Home Wiki*.

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.

- 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). At least one of the entrances will be a door with a handle (not a knob).
- 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 3.1(a).



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

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 Predefined objects

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

1. **Definition:** The TC will compile a list of 25 objects. There are no restrictions on object size, appearance or weight. However, it can be expected that the selected objects are easily manipulable by a human using a single hand.
2. **Object classes:** Each object will be assigned to an *object class*. The objects 'lemonade' and 'ice tea' may be of class 'beverage' for example.
3. **Object (class) locations:** Each object (class) will be assigned to an *object location*. Objects of class 'drink' may be usually found on the 'kitchen table' for example.
4. **Announcement:** The TC makes the set of objects (and their names, classes, and usual locations) available during the setup days.

- 5. Known vs. unknown:** These objects are used as the *known objects* in the test specifications; *unknown objects* are not taken from the set of *predefined objects*.
- 6. Placement:** 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 5cm space around each object.

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 20 locations out of the set of predefined locations as being *manipulation locations*. Whenever a test involves manipulation, the object to manipulate will be placed at one of the manipulation locations.

3.2.7 Predefined rooms

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

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

3.2.8 Predefined (person) names

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

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

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

3.2.9 Wireless network

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

- To avoid interference with other leagues, this 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.

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, the Demo Challenge and the Finals both robots can be used simultaneously.

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 receives 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 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, the Demo Challenge, and the finals, external devices are allowed, still their use needs to be announced beforehand.
- 5. Wireless devices:** All *wireless devices* including bluetooth devices, walkie-talkies, and anything else that uses an RF signal to operate need to be announced to the *Organizing Committee (OC)*. The use of any wireless device not approved by the TC is strictly prohibited.
- 6. Artificial landmarks:** *Artificial landmarks* and *markers* are not allowed.
- 7. Computing devices:** External computers for decentralized computations are allowed, 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. The *Open Challenge* is the open demonstration in Stage I.
2. **Stage II:** The best *50% of teams*¹ (after Stage I) advance to *Stage II*. Here, more complex abilities or combinations of abilities are tested. The *Demo Challenge* is the open—but scoped—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 addition, a Technical Challenge (see Section 7.1) is carried out between Stage II and the Final Demonstration, and its schedule is outside the scope of the Stage system. 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 *five (5)*.
2. In Stage II, the *maximum number of tests* that a team can participate in is *four (4)*.
3. None of the tests is mandatory, except for the *Robot Inspection* test (see Section 4.4), the *Robo-Zoo* test (see Section 5.1), and the *Basic Functionalities* test (see Section 5.2).
4. Teams have to indicate to the organizing committee 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*.

¹If the total number of teams is less than 20, then the best 10 teams advance to Stage II.

3.5.4 Score system

1. **Stage I:** The maximum total score per test in Stage I is *2000 points*.
2. **Stage II:** The maximum total score per test in Stage II is *2600 points*.
3. **Special tests:** Tests may specify a maximum total score deviating from the general maximum total scores.
4. **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.
5. **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.
6. **Partial scores:** All tests—except for the open demonstrations—are rewarded on a partial scoring basis.
 - 6.1. Tests are split into designated parts.
 - 6.2. Each part is assigned a certain number of points.
 - 6.3. A team that successfully passes a designated part of the test receives points for that part.
 - 6.4. In case of partial success, referees (and TC members) may decide to only award a percentage instead of the full partial score.
 - 6.5. The total score for a test is the sum of partial scores.
 - 6.6. Partial scores can be negative (e.g. to penalize failures etc.).

3.5.5 Open Demonstrations

1. **Stage I:** The *Open Challenge* is the open demonstration in Stage I.
 - 1.1. To participate in the Open Challenge, a team needs to participate in at least one regular Stage I test.
 - 1.2. Teams can demonstrate freely chosen abilities.
 - 1.3. The performance is evaluated by a jury consisting of the team leaders of all other teams.
 - 1.4. The Open Challenge is described in Section 5.5.
2. **Stage II:** The *Demo Challenge* is the open demonstration in Stage II.
 - 2.1. To participate in the Demo Challenge, a team needs to participate in at least one regular Stage II test.
 - 2.2. The scope (and topic) of the Demo Challenge are defined by the TC on a yearly basis.
 - 2.3. Teams can demonstrate freely chosen abilities, but according to the scope.
 - 2.4. The performance is evaluated by the Technical Committee.

2.5. The Demo Challenge is described in Section 6.4.

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. There 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. Both juries have different sets of evaluation criteria.

3.3. Members of the external jury are selected by the Executive Committee on site.

3.4. The demonstration in the finals does not have to be different from the one shown in the Open or Demo 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 can be excluded from the ongoing competition immediately by a decision of the RoboCup@Home Technical Committee. Furthermore, the team and its members can 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, the Demo Challenge and the final demonstration, 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. But since the “safety first” rule (Section 3.6.1) supercedes all other rules, it is suggested to not touch anything. 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., 30s) is removed.
- 3.2. A non-moving robot blocking the path of another robot for longer than a reasonable amount of time (e.g., 30s) 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 is a penalty of *100 points* for using a start button.

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.
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.
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:** The 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 (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 allotted 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*.

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 declared in the registration form and checked 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 dialogues 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:** 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.

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 *500 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 *-100 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 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 *500 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 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 beforehand.
4. It is the decision of the 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.

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 5).

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

Setup & Preparation	Stage I	Stage II	Finals
	$\xrightarrow{\text{advance}}$ All teams that passed Inspection	$\xrightarrow{\text{advance}}$ Best 10 (<20 or best 50% (≥ 20)	$\xrightarrow{\text{advance}}$ Best 5 teams

4.1 General Setup

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

1. **Start:** Setup & Preparation starts when the venue opens for the first time.
2. **Intention:** During Setup & Preparation, teams arrive, bring or receive their robots, and assemble and test them.
3. **Tables:** The local organization will setup and randomly assign team tables.
4. **Groups:** Depending on the number of teams, the organizing committee (OC) may form multiple groups of teams (usually two) for the first (and second stage). The OC will assign teams to groups and announce the assignment to the teams.
5. **Arena:** The arena is available to all teams during Setup & Preparation. The OC may schedule special test or mapping slots in which arena access is limited to one or more teams

exclusively (all teams get slots). Note, however, that the arena may not yet be complete and that last works are conducted in the arena during the setup days.

- 6. Objects:** The delegation of EC, TC, OC and local organizers will buy the objects (see Section 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 & Poster Session

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 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 Section 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 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 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 *1000 points* (i.e., multiplied by $100/3$). 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:

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

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 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 waypoint 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 3.3), checking in particular:
 - emergency button(s)
 - start button (if the team is going to require it)
 - collision avoidance (a TC member steps in front of the robot),
 - robot speaker system (plug for RF Transmission)
 - size
 - use of external devices (including wireless network)
 - 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 300 points.
- 7. Accompanying team member:** Each robot is accompanied by only one team member.
- 8. Registration form:** Every team needs to fill out a registration form which is brought to the TC by the accompanying team member.
- 9. 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.
 - Prepare and distribute registration sheets (external devices etc., place for notes and signatures of TC and team leader).
 - Prepare and distribute poster session evaluation sheets.

Chapter 5

Tests in Stage I

- Stage I starts with the Robo-Zoo test, and the Basic Functionalities test (BF). Participation in these regular tests is mandatory.
- Stage I features the following additional regular tests:
 1. Follow me
 2. Emergency Situation
- The open demonstration in Stage I is the open challenge. Participating in the open challenge requires participating in at least one regular test and in the mandatory tests.

5.1 Robo-Zoo

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.

5.1.1 Enclosed Space Dimension

The enclosed space is estimated to be around 2x2 meters. However, teams should expect reasonable deviations in these dimensions, since space in the venue may require smaller enclosed spaces.

5.1.2 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.

5.1.3 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.

5.1.4 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.

5.1.5 Score Sheet

The maximum time for this test is *60 minutes*.

Action	Score
Maximum score won by most tokens.	<i>500</i>
Tokens awarded to winning team.	
Tokens awarded to this team.	
<i>Special penalties & bonuses</i>	
Not attending (see sec. 3.7.1)	-500
Outstanding performance (see sec. 3.7.3)	<i>50</i>
Total score (excluding penalties and bonuses)	<i>500</i>

Normalization: The teams with less tokens than the best team get proportional scores based on the number of tokens they received, e.g

$$\text{score for this team} = 500 \times (t_{\text{this}}/t_{\text{best}})$$

where $t_{\text{this}}, t_{\text{best}}$ is the number of tokens received by this team, and the number of tokens received by the best team.

5.2 Basic Functionalities

This test is a series of small (atomic) activities that test basic functionalities expected to be applied throughout the competition.

Each atomic test has a duration of 3 minutes and no restart or CONTINUE are available. When the time has finished, or if the robot finished the test before the allotted time, the robot moves to the area of the next atomic test and gets ready within additional 2 minutes. While the team may move the robot manually or through direct control, additional points are given if the robot is able to autonomously prepare to start the next atomic test (see scoring).

The steady movement of the robot between locations is important, as this test will be conducted in an interleaved way: while one robot works on a functionality, the next robot performs the preceding functionality. To avoid logistic issues, whenever a robot has finished one atomic test, it should wait inside its current area for a command from one team member (i.e. a move/stop gesture or spoken move/stop commands) to start the next atomic test. If the robot does not follow these commands, or if a robot is required to be moved manually to the area of the next atomic test, it is the team's responsibility to immediately stop/move the robot such that it does not obstruct the performance of other robots. If the robot continuously hinders the execution of the test of another robot, the TC decides for the removal of the robot.

5.2.1 Basic Functionalities

All objects and locations in the following list are announced beforehand. The OC selects 5 objects from the list of objects described in 3.2.5.

The atomic tests are as follows:

- 1. Pick and Place:** The robot moves to a location where two objects are located (one known, one unknown). The robot is expected to pick one up and place it at another location. If the robot picks up the known object, it should place it at the location assigned to the category of the object; if the unknown object is picked up, it should be placed in the waste bin. To avoid having the robot move outside the area of this atomic test, these locations will all be inside the area of the atomic test and will be announced well before the start of the test.
- 2. Avoid That:** The robot should move to a location in the arena. The TC members will place two obstacles in the path of the robot. The first obstacle is avoidable (i.e. a chair): the robot should not touch it but keep on moving to the location. The second obstacle is unavoidable (i.e. a closed door), in which case the robot is expected to re-plan its route to the location.
- 3. What Did You Say?:** The robot goes into a room with a person (TC member) in it. It should find the person, move near that person, announced it has found her, and initiate small talk. The robot can ask the person to walk in front of it, if it is not able to detect the person. In this case, the robot will not score for person detection. The robot will be asked 3 of 10 pre-announced questions by the person in the form of general trivia (i.e. "What is the capital of Germany?", "What is the heaviest animal in the world?", etc.). Without confirmation, the robot should say the question that it heard and provide an appropriate answer.

5.2.2 OC instructions

6h before test:

- Specify and announce which 5 objects will be used in the test.
- Specify and announce the starting locations of all atomic tests, as well as the locations of where the objects should be placed depending of their category.
- Specify and announce 10 questions.

5.2.3 Score Sheet

The maximum time for each test is *3 minutes*.

Action	Score
<i>Pick and Place</i>	
Object picked up.	150
Object placed in appropriate location.	150
<i>Avoid That</i>	
Autonomously prepared to start atomic test.	50
Avoided obstacle.	100
Detected un-avoidable obstacle and re-planned route.	150
<i>What Did You Say?</i>	
Autonomously prepared to start atomic test.	50
Person found.	150
Question recognized and answered.	3×50
Autonomously leaving the arena after finishing the atomic test.	50
<i>Special penalties & bonuses</i>	
Not attending (see sec. 3.7.1)	-500
Outstanding performance (see sec. 3.7.3)	100
Total score (excluding penalties and bonuses)	1000

5.3 Follow Me

The robot has to safely follow an unknown person through a public space.

5.3.1 Focus

This test focuses on tracking and recognizing a previously unknown person, basic interaction and signaling capabilities, and safe navigation in unknown environments and narrow spaces with other people walking around or blocking the way.

5.3.2 Setup

1. **Location:** The test takes place outside the arena in a public space.
2. **Operator:** A “professional” operator is selected by the TC to test the robot.
3. **Other people:** There are no restrictions on other people walking by or standing around throughout the complete task.
4. **Path:** A path is setup (but *not* announced) beforehand. The complete path is divided into three sections by two intermediate time points (ITPs).

5.3.3 Task

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 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).
2. **Memorizing the operator:** The robot has to memorize the operator. During this phase, the robot may instruct the operator to follow a certain setup procedure.
3. **Following the operator:** When the robot signals that it is ready to start, the operator is walking—in a natural way—on the designated path. The robot needs to follow the operator. The robot deals with different obstacles (single persons, tight elevator rooms, and small crowds) in different sections. Each section has a separate time measurement, but the complete task needs to be performed within the overall task time.
 - 1st section (from start to first ITP): Two persons block the direct passage on the way to the first ITP (at different positions). The operator guides the robot around the persons. One of the persons starts walking when the robot approaches, and crosses the way between robot and guide. Right in between, the walking person stops for 3 s before walking away.
 - 2nd section (between first and second ITP): The operator guides the robot into a small tight room (e.g., an elevator). There is not enough space to freely operate in this room (e.g., 1 m × 2 m). Other people may already be in there causing that operator and robot have to leave in reverse order (of entering). The team may choose among the following options and instruct the operator accordingly when the test starts.

1. The operator enters first, and commands the robot to exit when leaving. The robot is expected leave the room (the door should be cleared), wait for the operator, and automatically follow the guide again. No further command is given to tell the robot that it should follow again.
2. The operator commands the robot to enter first, and exits first when leaving. The robot is expected to enter the room (the door should be cleared), wait for the operator, and automatically follow when the operator leaves the room again.

Both commands must be naturally spoken commands such as “leave the elevator”. Remotely controlling the robot in the form of specifying positions, orientations or movements is not allowed. Between entering and leaving the room, the door is shut for at least 5s. In case the room is not directly accessible, the time is stopped while waiting.

3rd section (between second ITP and finish line): A small crowd of people (4-5) will be waiting outside the room, blocking the way between the second ITP and the finish line. The operator sneaks through the crowd and waits for the robot on the other side. The robot cannot pass through the people and needs to autonomously navigate around the group. While waiting, the operator is allowed to signal the robot where it is standing (e.g., by waving or by making a sound), but it is not allowed to move back. After the robot is following the operator again, the operator proceeds to the finish line.

5.3.4 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. **Natural walking:** The operator has to walk “naturally”, i.e., move forward facing forward. If not mentioned otherwise, the operator is not allowed to walk back, stand still, signal the robot or follow some re-calibration procedure.
3. **Asking for passage:** The robot is allowed to (gently) ask individual persons to step aside, but it is not allowed to blindly shout at groups of people.
4. **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.
5. **Instruction:** The robot interacts with the operator, *not* the team. That is, the team is only allowed to (very!) briefly instruct the operator
 - how to tell the robot to follow,
 - how to visually/acoustically signal it (e.g., waving or calling the robot’s name), and
 - how to command the robot into or out of the tight room (ITP 2); the operator is allowed to indicate both the entry and exit of the elevator only by a single command.
6. **Calling the operator back:** When the robot has lost the operator, it may call the operator back once per section (losing the points for that section).

- 7. Time measurement:** The time of the first section (from start to first ITP) is started when the operator steps in front of the robot.

5.3.5 OC and Referee instructions

Any time before the test:

- Define the path and ITPs where the time is measured.
- Select the “professional” operator(s).

During the test:

- Show the path and the ITPs to the operators.
- Take the (accumulated) time at each ITP and at the finish line.
- Check that the elevator door is closed for the specified time.
- Check safe operation of the robot; the robot needs to be stopped immediately if a person is going to be touched by the robot

5.3.6 Score Sheet

The maximum time of the test is *8 minutes*.

Action	Score
<i>Points for the 1st Phase</i>	
Avoided the non-moving person.	50
Avoided the moving person.	50
for the best time Δt_1 achieved in section 1, less points are given for longer times (see Normalization)	200
<i>Points for the 2nd Phase</i>	
Entered elevator.	50
Follow operator after getting out of elevator.	50
for the best time Δt_2 achieved in section 2, less points are given for longer times (see Normalization)	200
<i>Points for the 3rd Phase</i>	
Navigate around group.	50
Follow operator behind the group.	50
for the best time Δt_3 achieved in section 3, less points are given for longer times (see Normalization)	200
<i>Additional points</i>	
completing the full task	100
<i>Special penalties & bonuses</i>	
Not attending (see sec. 3.7.1)	-500
Outstanding performance (see sec. 3.7.3)	100
Total score (excluding penalties and bonuses)	1000

Timed Scoring Remarks: The time score is based on the (accumulated) time taken at each ITP (intermediate time point) and at the final goal point (e.g. $t_1 = 125sec, t_2 = 305sec, t_3 = 425sec$). Then the time intervals needed for each section are computed (e.g. $\Delta t_1 = 125sec, \Delta t_2 = 180sec, \Delta t_3 = 120sec$). The scores are then normalized with regard to the best time interval achieved for this section (e.g. $\Delta t_1^{min} = 100sec, \Delta t_2^{min} = 90sec, \Delta t_3^{min} = 120sec$). In the example a complete score of $150 + 100 + 200 + 100 = 550$ points is achieved:

If a team needs more time in a section than the best team, the score for that section i is computed by

$$\text{normalized score for section } i = 200 \times (\Delta t_i^{min} / \Delta t_i)$$

where $\Delta t_1 = t_1 - 0, \Delta t_2 = t_2 - t_1, \Delta t_3 = t_3 - t_2$, and $\Delta t_1^{min}, \Delta t_2^{min}, \Delta t_3^{min}$ are the minimum time

intervals achieved by a team.

5.4 Emergency situation: home accident

The robot has to properly react to an emergency situation in the house. The main story of this test is: The house is owned by an elderly person who is currently alone at home. Unfortunately, the person has an accident and requires immediate help. The robot detects the emergency, e.g., by hearing/seeing the person fall over, or perceiving the person attracting attention through waving/calling. The robot moves to the person to learn more about the situation. It notifies an ambulance and continues with first aid activities. It also has to carry all of this out as fast as possible.

5.4.1 Focus

The test focuses on automatic detection of events related to safety, security, and human-robot interaction in order to improve safety and security in the house in case of emergencies. Implementation of a complex behavior containing several possible cases, in an efficient way, is a requirement to solve this task.

5.4.2 Setup

- 1. Location:** The test takes place inside the arena.
- 2. Person in the arena:** The referees decide the location of the person in the arena (a similar setting for all the teams not known before the test). Such person, in addition to being fluent in English, should be a “professional victim”, meaning that he/she should act out the part of suffering an accident (such as a heart attack, diabetic incident, have tripped down, etc.), but at the same time be weary of what the robot is doing and what it is asking to do and follow any indications by the TC to carry on the test.
- 3. Person position before the accident:** The person is expected to be in a standing comfortable position before the accident. In addition, the person may be wondering around the room.
- 4. Person position after the accident:** The person is expected to be in an uncomfortable position after the accident. For example, sitting on a chair, lying on the ground, sitting on the ground, etc.
- 5. Person behavior after the accident:** The person will try different sort of hints to get the attention of the robot. Waving, shouting, coughing are examples of such behavior.
- 6. Timing:** The total time for this test is 7 minutes. The referee decides for the time of accident. It will happen at a random time between 30 seconds and 1 minute after the start of the test (enough time for the robot to be inside the room). The time from the start when the “accident” happens until the ambulance has reached the location of the person is measured. This additional timer will provide a measure of how efficient the robot responds to the situation, and will provide a time with which the total points of the test will be normalized.

5.4.3 Task

Robots participating in this test are required to implement a behavior summarized with the following pseudo-code. This behavior includes different cases. We require teams to implement the entire behavior even though only a part of it may be actually executed during the competition. The exact situation will be decided by the TC before the test, but it will not be announced to the teams.

MAIN TASK

```
enter the apartment
drive into the room in which the person is situated
observe the event of emergency and announce it has happened (start timer)
approach the person
ask the person about her/his status
register person position
save collected information as a report to the ambulance
ask person what to fetch (water, first aid kit, cell phone)
bring desired object
go to entry of apartment
wait for ambulance or called friend
guide ambulance/called friend to location of person (stop timer)
```

5.4.4 Additional rules and remarks

(1) Creating a report is implemented by producing a PDF file with relevant information about the situation that occurred. This file should include for example:

- map of the environment
- person's location in the map
- images of the person
- state of the person

The person in an accident must be documented as an image of the person at his/her location after the accident and must be included in the report.

These information must be compiled into a PDF file that is collected by the referee on a USB stick immediately after the test is finished with no manual processing. A USB stick must be mounted on the robot before the test starts and the report should be saved in this stick within the time of the test. When the test finishes the referees will collect the stick from the robot (without any manual intervention by the team members). This report will be evaluated by TC/referees (possibly also by experts from the Rescue league). Evaluation will be based only on correctness, completeness, and usefulness of information provided.

5.4.5 OC and Referee instructions

2h before the test:

- Announce which objects from the list of known objects the person may ask for.

Before the test session:

- Define the specific situation (i.e., position and status of the person).

Before each test:

- Place the objects and the person in the apartment.

During the test:

- Take the time when the robot enters the area of the person and check that it proceeds with the test not before the accident happened
- Start timer when the accident happens and stop it when the ambulance is directed towards the person
- Check that the robot clearly announces the detection of the person in accident
- Count the number of times talking to something that is not a person

5.4.6 Score Sheet

The maximum time for this test is *7 minutes*.

Action	Score
Announcing that the accident happened at most 5 seconds after it happened.	<i>200</i>
Automatically approach person when in need of help and asking for his/her status	<i>100</i>
Talking to something that is not a person	<i>-100</i>
Correctly understanding the object desired by the person	<i>100</i>
Grasping the correct object and lifting it for more than 5 sec	<i>100</i>
Delivering the correct object to the person	<i>150</i>
Waiting for the ambulance or called friend at the entry and guiding them to the person	<i>150</i>
 Report	
Up to 200 points (decided by TC/referees) are awarded for usefulness/completeness of information in the PDF report	<i>200</i>
 Special penalties & bonuses	
Not attending (see sec. 3.7.1)	<i>-500</i>
Using start button (see sec. 3.3.5)	<i>-100</i>
Outstanding performance (see sec. 3.7.3)	<i>100</i>
<hr/>	
Total score (excluding penalties and bonuses)	<i>1000</i>

Time Normalization: The 100% of the awarded points will be given to the team with the best time (t_{min}). For the rest of the teams their normalized score is computed by

$$\text{normalized score}_i = \text{score} \times (t_{min}/t)$$

The factor t_{min}/t cannot be less than 0.5.

Penalty for Asking Person to Approach: If a team is not able to detect the accident or approach the person in need of help, the robot may ask the person to come closer to the robot and carry out the rest of the test. However, 1 minute is added to its time as penalty and no points will be awarded for the following parts of the test: announcing the accident and approaching the person.

5.5 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. To participate in this test, a *Challenge Registration Form* (see below) needs to be filled out and provided to the TC 5 hours before the test begins. In this form, several enquiries are asked for, such as a brief summary of the demonstration, its motivation, and its novelty in the field.

5.5.1 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.

- 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.

5.5.2 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 to the demonstration.
- For the presentation, the team can show up to two slides with the above content and the team's evaluation.
- 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.

5.5.3 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.

5.5.4 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 *2000 points* (i.e., multiplied by $200/6$).

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:

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

5.5.5 Additional rules and remarks

- There is no fixed start signal in this test.
- Not providing a team member for the jury (on time) results in no score for this team in the open challenge. In severe cases, additional penalties may apply (see Section 3.7.2).
- An EC, TC, or OC member (not necessarily the same person for all teams) guides through the open challenge, moderates the interview part of the challenge, and takes the time(s).

Open Challenge

Test Description

Test Information

Team name: _____

Main ability: _____

Test objective: _____

Abilities used:

- Audio processing
- Artificial Intelligence
- Computer vision
- Endurance / Strength
- Human-Robot Interaction
- Learning
- Manipulation
- Navigation
- Other: _____

Novelty and scientific/league contribution

Test Description

Chapter 6

Tests in Stage II

- Stage II features the following regular tests:
 1. Cocktail Party
 2. E-GPSR
 3. Restaurant
- The open demonstration in Stage II is the demo challenge. Participating in the demo challenge requires participating in at least one regular test.

6.1 Cocktail Party

The robot has to learn and recognize previously unknown persons, and deliver drinks.

6.1.1 Focus

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

6.1.2 Task

- 1. People setup:** 5 people are distributed in a predefined “party room” either sitting or standing, some of them forming groups of 2 or 3 people.
- 2. Entering:** The robot enters the arena and navigates to the party room.
- 3. Getting called:** Three out of 5 persons are assigned drink orders by the referees. The robot waits for being called by the persons (also through waving). The persons call simultaneously for the robot. The robot has to approach one of the calling persons then do the learning procedure and take the order. The robot can decide to skip the detection of the calling and ask one person to walk in front of it. In this case, the referees determine the person to approach the robot. The calling person introduces her/himself by name before giving the order of a drink. The robot leads the dialogue to learn the person and retrieve her/his drink order.
- 4. Taking the order:** The calling person gives order of a specific drink to the robot. The robot can request for more orders or start to fetch the object from a different room. In the first case, the robot searches for the remaining calling persons. During the search process, the robot is allowed to either ask persons to call for it again, or to ask persons to come to it and to give a new order. In both cases the robot may call into the room.
- 5. Getting the drinks:** The robot has to navigate to a designated location in another “storage room” where drinks are stored. The robot may grasp any number of drinks, e.g., all the drinks ordered, or just one, and return to the party room.
- 6. Delivering the drinks:** While the robot fetches drinks, the persons may change their places within the party room (on request of the referees). The robot has to search for persons, recognize found persons, and deliver the correct drink if there is an order for the recognized person. If the robot comes to the place the person ordered and the person is not there, then it could call the person loud, the person should respond (either sound or waving hand) and the robot must go to that place (check the person identity).
- 7. Leaving the arena:** After delivering all the drinks, the robot has to leave the arena.

6.1.3 Additional rules and remarks

- 1. Repeating names:** The robot may ask to repeat the name if it has not understood it.

2. **Misunderstood names:** If the robot misunderstands the name, the understood (wrong) name is used in the remainder of this test.
3. **Misunderstood order:** If the robot does not understand the order, it can continue with an own assignment of drinks to persons or with a wrong, misunderstood assignment.
4. **Approaching non-calling persons:** If the robot approaches a person that is not calling and asks for an order, the person indicates that she/he does not want to order anything. No points can be scored for understanding names or orders, or for grasping or delivery for a non-calling person.
5. **Changing places:** After giving the order (when the robot is not in the party room), the referees may re-arrange the persons including their body posture. That is, a sitting person may change to a standing posture and vice versa.
6. **Positions and orientations:** All persons roughly stay where they are (if not asked to move by the referees), but they are allowed to move in certain limits (e.g. turn around, make a step aside). They do not need to look at the robot, but are requested to do so, when instructed by the robot.
7. **Asking for help:** If the robot is not able to grasp a drink either because it does not have any arms or it fails grasping, the robot may ask for help and a referee can hand over the object (losing points for grasping that drink). The robot has to clearly indicate that it has recognized the correct drink, e.g., by facing the drink, naming it and telling its rough position (e.g., leftmost, rightmost etc.) relative to the other drinks on the table. The robot may only ask for help once during the pickup phase.
8. **Correct delivery:** The drinks do not have to be handed over to the user. Putting them on the ground or asking the user to grab them from some kind of tray is allowed. When taking a drink from the robot, a sitting person may stand up in order to get it. However, in case the robot is carrying more than one object at a time, a delivery is only considered successful when there is an easily comprehensible mapping from grasped objects to recognized persons. The robot must be close to the person (within 1 m) for delivery and indicate uniquely which person it addresses by calling it by name and either facing her/him or pointing at her/him (e.g., with object in hand). When putting all the drinks on a tray, the robot has to name the correct drink and indicate its rough position relative to the others.
9. **Empty arena:** During the test, only the robot and only 5 persons are in the arena. The door opener, the referees and other personnel that is not assigned as test persons will be outside the scenario.
10. **Calling instruction:** The team needs to specify before the test which ways of getting the attention of the robot are allowed. This can be waving, calling or both of them. The robot can also decide to skip this part, by asking for persons to get close to it.
11. **Announcement of locations:** Both the locations of the drinks and the rooms where the test takes place are announced beforehand. Note that there may be more objects at the drink location than the ordered drinks.

6.1.4 Referee instructions

The referees need to

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

6.1.5 OC instructions

2h before test:

- Specify and announce the rooms where the test takes place and where the pickup location is.

6.1.6 Score Sheet

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

Action	Score
<i>Taking the orders</i>	
Detecting the calling persons	3×150
Understanding and repeating the correct person and the order (half points are given if either of the names is incorrectly understood)	3×100
<i>Grasping drinks</i>	
Grasping an ordered drink (and successfully lifting it up to at least <i>5 cm</i> for more than <i>10 seconds</i>)	3×200
<i>Delivering drinks</i>	
Delivering the correct ordered drink	3×200
<i>Leaving the arena</i>	
Autonomously leaving the arena within the time limit	<i>50</i>
<i>Penalties</i>	
Talking to the wrong person (using wrong name)	<i>-50</i>
Talking to something that is not a person	<i>-150</i>
<i>Special penalties & bonuses</i>	
Not attending (see sec. 3.7.1)	<i>-500</i>
Using start button (see sec. 3.3.5)	<i>-100</i>
Outstanding performance (see sec. 3.7.3)	<i>200</i>
Total score (excluding penalties and bonuses)	<i>2000</i>

6.2 Enduring General Purpose Service Robot

This test evaluates the abilities of the robot that are required throughout the set of tests in stages I and II. In this test the robot has to solve multiple tasks upon request over an extended period of time (30-45 minutes). That is, the test is not incorporated into a (predefined) story and there is neither a predefined order of tasks nor a predefined set of actions. The actions that are to be carried out by the robot are chosen randomly by the referees from a larger set of actions. These actions are organized in three categories with different complexity. Scoring thereby depends on the complexity class.

6.2.1 Focus

This test particularly focuses on the following aspects:

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

6.2.2 Task

- 1. Entering and command retrieval:** The robot is started at a designated position within the arena where it has to wait for further commands.
- 2. Command generation:** A command is generated randomly, depending on the command category chosen by the team (see below).
- 3. Command categories:** The team may choose from the following three categories:
 - 3.1. Category I:** 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.
 - 3.2. Category II:** The robot gets a command that does not include all the information being necessary to accomplish the task. The actual commands will be under-specified by, for example:
 - only giving the class of the object (“bring me a drink”) or location (“go to the table”), and not the actual object or location, or
 - not providing the location (or its class).

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

- 3.3. Category III:** The command contains erroneous information. The robot should be able to realize such an error while trying to carry out the task, get back to the operator, and clearly state **why** it wasn't able to accomplish the task. There are extra points if the robot is able to solve the problem by an alternative, reasonable solution (see score sheet).
- 4. Task assignment:** The robot is given the command by the operator and may directly start to work on the task assignment.
 - 5. Task execution:** The robot must stop the execution of a task and return to its designated position within 5 minutes. Otherwise the robot must be moved to its designated position immediately. If a restart is still available to the team, it can be restarted at the designated position.
 - 6. Returning:** After accomplishing the assigned task, the robot has to move back to its designated position to wait and retrieve the next command (i.e., go back to **1.** without the need of re-entering the arena). The robot can work on at most three commands.
 - 7. Timing:** The total time allotted to the robot for command retrieval and task execution is 10 minutes. If the robot is not at its designated position after the time has expired, it must be moved at its designated position immediately.

6.2.3 Additional rule and remarks

- 1. CONTINUE rule:** Teams are able to use the CONTINUE rule in this test, with all the standard penalties it involves. The CONTINUE rule can only be used with the custom operator (e.g. both penalties of custom speaker and CONTINUE rule will be applied).
- 2. Number of Teams and Scheduling:** In each test slot, 3 teams will be competing in the arena concurrently. The robots will be tested in an interleaved fashion: The robots will retrieve commands and execute the task one after the other. As stated above, each robot will have a maximum amount of 5 minutes per command (including time for retrieving the command and executing it). However, the sum of each of the times it took to carry each command should not exceed 10 minutes. This means that if the robot took 4 minutes to carry out its first command and another 4 minutes for its second command, it only has 2 minutes to carry out its third command. However, if it only took 2 minutes for the first and 2 minutes for the second, it still only has 5 minutes for the third. To facilitate a fluent and untroubled performance of the robots, the other robots must always return or being returned to their designated position before the next robot will be given a command. If a robot moves from its designated position while another robot is working on a command, it must be immediately disabled and moved to its designated position. If a restart is still available to the team, it can be restarted at its designated position. To carry the robot, at most two team members are allowed in the arena, and the robot must be moved as quickly as possible. To start or restart the robot, at most one team member may operate the robot. The team members moving and operating the robots must leave the arena immediately after the robot is placed or started.

- 3. Referees:** Since the score system in this test involves a subjective evaluation of the robot's behavior, the referees are EC/TC members. One referee is assigned to each team to judge performance, to measure the time for working on a command, and to keep track of the overall operating time of the robot.
- 4. Category selection:** For every of the three commands given to the robot, the team chooses the desired command category. Points are scored per category with the total score of the test being the sum of the maximal number of points scored in each category (see score sheet).
- 5. 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 3.6.11).
 - With the custom operator, the team can only score 50 % of the points for the respective command.
- 6. Restarts/Changing/Charging batteries:** The team may install a charging station at the designated position of the robot, if it does not hinder the other robots. However, the robot must connect itself with the charging station after carrying out a command. Changing batteries or manually connecting the robot with the charging station is allowed during a restart. The general rules for restart apply.

6.2.4 OC and Referee instructions

2h before test:

- Specify and announce the designated position for each team

During the test:

- Generate random sentences by an automatic sentence generator

6.2.5 Score Sheet

The maximum accumulated time per team for this test is *10 minutes*. The maximum time for working on a command is *5 minutes*.

Action	Score
<i>Command Category I</i>	
Performing the first command correctly	200
Performing the first and second command correctly	200
Successfully solving the complete task and returning to designated position	200
<i>Command Category II</i>	
Asking reasonable questions to obtain missing information	300
Solving half of the task or more (showing that the robot has understood the command and works on the test)	200
Completely solving the task and returning to designated position	400
<i>Command Category III</i>	
Solving the task up the point where the error occurred	300
Indicating that a problem has occurred while executing the task	200
Returning to the designated position and explaining what went wrong	300
Giving an alternative solution to the problem	200
<i>Penalty for own operator</i>	
Reduction of points for every command provided by a team member	0.5×-1
<i>Total Score</i>	
$\max(\text{Cat. I}) + \max(\text{Cat. II}) + \max(\text{Cat. III}) = 2500$	
<i>Special penalties & bonuses</i>	
Not attending (see sec. 3.7.1)	-500
Outstanding performance (see sec. 3.7.3)	250
<hr/>	
Total score (excluding penalties and bonuses)	2500

6.3 Restaurant

6.3.1 Focus

The focus of this test is mobile manipulation in a real environment, such as a restaurant or shopping mall. Since the environment is initially unknown, this test requires online SLAM, i.e., mapping the shop in a guide phase and using the map instantaneously for localization and navigation in a navigation/manipulation phase.

6.3.2 Task

1. Guide phase:

- 1.1. A robot is guided through the environment by one of the team members where the robot is shown *five locations*, two of which are *object location* and the other three are *delivery locations*. Each object location contains several objects of the same class. All locations have an associated label that the user needs to specify to the robot.
- 1.2. After reaching all five locations, the user guides the robot to a (predefined) *ordering location*.

2. Navigation and manipulation phase:

- 2.1. At the *ordering location*, the user places a delivery order of *three* objects, in total, to *two* delivery locations, e.g., “Bring objects A and B to location 1, and object C to location 2”.
- 2.2. The robot has to retrieve the objects from their corresponding shelf and bring them to the respective delivery locations.
- 2.3. After carrying out the delivery order, the robot returns to the *ordering location*.

6.3.3 Additional rule and remarks

1. **Safety!** This test takes place in a public area. That is, there may be people standing, sitting or walking around the area throughout the test. The robot is expected to not even slightly touch anything and is immediately stopped in case of danger.
2. **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.
3. **Start:** There is no fixed start signal in this test.
4. **Order:** The way the user provides such information to the robot is up to the robot’s team.
5. **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).

- 6. Natural walking:** The operator has to walk “naturally”, i.e., move forward facing forward. If not mentioned otherwise, the operator is not allowed to walk back, stand still, signal the robot or follow some re-calibration procedure.
- 7. Disturbances from outside:** If a person from the audience (severely) interferes with the robot in a way that makes it impossible to solve the task, the team may repeat the test immediately.

6.3.4 Score Sheet

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

Action	Score
<i>Guide Phase</i>	
Reaching a <i>location</i> in the guide phase	5×50
<i>Navigation Phase</i>	
Reaching a (task-relevant) <i>location</i> in the manipulation phase	4×100
<i>Grasping the correct objects</i>	
Successfully grasping a correct object from a shelf	3×450
<i>Delivering the correct objects</i>	
Successfully delivering the correct object to the correct location	3×200
<i>Special penalties & bonuses</i>	
Not attending (see sec. 3.7.1)	-500
Using start button (see sec. 3.3.5)	-100
Outstanding performance (see sec. 3.7.3)	260
Total score (excluding penalties and bonuses)	<i>2600</i>

6.4 Demo Challenge

During the *Demo Challenge* teams are encouraged to demonstrate recent research results and the best of the robots' abilities. In contrast to the open challenge (Section 5.5), it is not a completely open but scoped demonstration. Teams are encouraged to pick up problems within the scope of the challenge, to demonstrate new abilities and applications, and to present them as if it were a product it could be sold. The scope of the demo challenge changes every year. To participate in this test, a *Challenge Registration Form* (see below) needs to be filled out and provided to the TC 5 hours before the test begins. In this form, several enquiries are asked for, such as a brief summary of the demonstration, its motivation, and its novelty in the field.

6.4.1 This year's focus

The theme of this year's demo challenge is "smart robots in smart homes". That is, the demonstration should focus on intelligent robots that are embedded in the smart homes of the future. The robots can demonstrate to interface sensors and active devices that are expected to be part of a smart home for a task that is of purpose to a user. What is demonstrated should be within the scope and *new*, i.e., nothing that has already been demonstrated in the previous tests or in previous competitions.

Possibilities include, but are not limited to:

- using cameras mounted in the environment to widen the field of view of the robot
- using wireless interfaces to get the state of or switch on/off devices such as TVs, kitchen appliances, etc.
- read RFID tags to retrieve information about objects
- show information on displays in the environment
- etc.

The used equipment for the smart home has to be brought and setup by the teams themselves as external devices.

6.4.2 Task

The Demo Challenge is an open demonstration which means that the teams may demonstrate anything they like (within the scope of the focus). The performance of the teams is evaluated by a jury consisting of all members of the technical committee.

The procedure for the challenge 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 *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.

6.4.3 Presentation

The demonstration should be considered like if it were of a product to be sold, so it should be practical and catchy.

1. **Elevator pitch:** At the beginning of the demonstration, the team has to briefly (maximum *one minute*) describe the addressed problem, what the robot is about to do, and the importance of the task with respect to the problem and the scope of the challenge.
2. **No presentation:** The rest of the demonstration should not feature a presentation, and on its own should make sense to the audience and the jury.

6.4.4 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.

6.4.5 Jury evaluation

1. **Jury:** The jury is constituted of members of the technical committee.
2. **Evaluation:** Both the demonstration of the robot(s), and the elevator pitch are evaluated. The jury can give a maximum of *1500 points* for factors such as
 - 2.1. complexity of the task and performance,
 - 2.2. marketability/story,
 - 2.3. safety,
 - 2.4. human-robot-interaction, and
 - 2.5. usability/appearance.

The actual scoring is not just normalized over all jury members, but discussed within the technical committee after the Demo Challenge.

6.4.6 Additional rules and remarks

1. **Abort on request:** At any time during the demonstration, the jury may interrupt and abort the demonstration
 - 1.1. 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;
 - 1.2. 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).
2. **Team-team-interaction:** An extra bonus of up to *500 points* can be earned if robots from two teams (4 robots maximum, 2 from each team) successfully collaborate (robot-robot interaction).
 - This bonus is earned for both teams.
 - The robot(s) of the other team must only play a minor role in the total demonstration.

-
- It must be made clear that the demonstrations from the two teams are not similar, otherwise the points cannot be awarded.
 - In case a team receives two (or more) bonuses, the maximum bonus will be taken.
 - The collaboration is possible even if one of the two teams has not reached Stage 2.
 - The team which does not participate in Stage 2 receives no points for this test.

Demo Challenge

Test Description

Test Information

Team name: _____

Main ability: _____

Test objective: _____

Abilities used:

- Audio processing
- Artificial Intelligence
- Computer vision
- Endurance / Strength
- Human-Robot Interaction
- Learning
- Manipulation
- Navigation
- Other: _____

Novelty and scientific/league contribution

Test Description

Chapter 7

Technical Challenge: People Activity Detection

7.1 Description

The aim of the *Technical Challenge* is to focus on a particular capability of a domestic service robot, and to compare the teams' performances in a realistic benchmarking setup. Every year, a new capability and a new challenge is selected to pick up recent state-of-the-art problems and progressively set harder goals. The definition, the setup on site and the evaluation of the teams' performances is done by the technical committee (TC).

There are no points for the technical challenge for the running competition. Instead, there is an award for winning the *Technical Challenge* (see Section 1.6.3).

It is not considered a regular test, and is conducted usually after Stage II (although the OC will announce the official time beforehand during competition). Participating in the *Technical Challenge* requires participating in at least one regular test of the competition (Stage I or II).

7.2 Concept and this year's focus

The focus of the 2014 technical challenge is People Activity Detection —an important capability for interaction-based robots in everyday environments. It is important to be able to perceive not only if a person is present or not, but also what the person is doing.

7.3 Arena setup

- The TC selects a room to be used and announces the room at least one day before the technical challenge.
- 5 persons in different positions and activities are positioned by the TC inside the room.
- The location of each person is announced beforehand.
- The positions and activities are modified between the individual entries.

7.4 Task

When the test starts, the robot has to move to the pre-defined locations, search for the person there and state in what position or activity is the person in. It shall state by either voice or

visual aids in a screen.

The positions can be:

1. Standing.
2. Sitting.
3. Laying down.

The activities can be:

1. Confused (presented by the person scratching their head).
2. Happy (presented by smiling).
3. Bored (presented by eyes-rolling and swaying back and forth).

7.5 Evaluation and scoring

1. **Time:** The total time in this challenge is *5 minutes*.
2. **Correct position detection:** For every position correctly detected **+1 point** is awarded.
3. **Correct activity detection:** For every activity correctly detected **+2 points** are awarded.
4. **Incorrect detections:** Confusing positions, activities or persons with objects, is penalized with **-1 point**. In addition, a wrong robot announcement (Sec. 7.4) is penalized with **-1 point**.

Each detection (position/activity) needs to be logged in a human-readable way. Positions of persons need to be documented by an image of the person and a bounding box around her/him. Activities are logged by images of the person in the moment of the activity, and a bounding box around the person with a textual annotation stating the recognized activity. The logs have to be saved on a USB stick that is attached to the robot at the beginning of the challenge. No manual modification of the data on the USB stick is allowed.

7.6 Additional rules and remarks

1. **Publication:** Mandatory for the participation in the technical challenge is the publication of the used approach (source and documenting technical paper) not later than six month after the competition. The team must send a notification to the official mailing list (`robocup-athome@lists.robocup.org`) when the above information is published. In case the source is not published within that period, the team is banned from future competition(s).
2. **Logging:** For further analyzing the own performance and those of the other teams, all detections are logged (as specified in Sec. 7.4). In addition, we encourage teams to also log sensory data that is used for the detection in common formats (e.g., PNGs for RGB-D images, PCD for point clouds, ROS bag files). The logged data is then collected, and distributed to the teams.

Chapter 8

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.

8.1 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.

8.1.1 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.

8.1.2 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.

8.1.3 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.

8.2 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.

Abbreviations

EC	Executive Committee	7
OC	Organizing Committee	8
TC	Technical Committee	8
TDP	team description paper	16

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