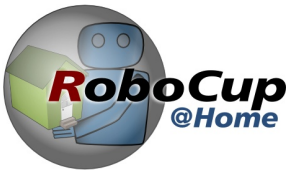

RoboCup@Home

Rules & Regulations

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Contents

Chapter 1

Introduction

1.1 RoboCup

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

1.2 RoboCup@Home

1.2.1 What is 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 colocated with the RoboCup symposium.

1.3 Organization

1.3.1 Executive Committee

The *Executive Committee* consists of members of the board of trustees, and representatives of each activity area.

Members representing the @Home league:

- Luca Iocchi (University of Rome "La Sapienza", Italy),

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- Javier Ruiz del Solar (Department of Electric Engineering, Universidad de Chile, Chile),
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- Tijn van der Zant (University of Groningen, Cognitive Robotics Laboratory, Groningen, The Netherlands),
  robotijn@gmail.com

1.3.2 Technical Committee

The *Technical Committee* (TC) is responsible for the rules of each league. The TC consists of the exec members from above and the members listed below.

Members of the RoboCup@Home league Technical Committee for 2011:

- Dirk Holz (University of Bonn, Germany)
  holz@ais.uni-bonn.de
- Anne-Lise Jouen (Université de Lyon, France)
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  komei.sugiura@nict.go.jp

1.3.3 Organizing Committee

The *Organizing Committee* (OC) is responsible for the organization of the competition. The OC consists of members listed below.

Members for the OC of the @Home league 2011:

- **Chair:** Sven Wachsmuth (Bielefeld University, Germany)
  swachsmu@techfak.uni-bielefeld.de
- **Local Chair:** Hatice Kose-Bagci (Istanbul Technical University, Turkey)
  hatice.kose@gmail.com
- Fariborz Mahmoudi (Qazvin Azad University, Iran)
  fzmahmoudi@gmail.com
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- Fernando Ribeiro (University of Minho, Portugal)
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1.4 Infrastructure

1.4.1 RoboCup@Home Mailinglist

The *official mailinglist* 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 website* that will also contain all of the rules and listing of registered teams can be found at

http://www.robocupathome.org/

1.4.3 RoboCup@Home Wiki

The *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. In *Stage I*, an *Open Challenge* is held. 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. There will be a 1^{st}, 2^{nd}, and 3^{rd} place award.

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.

Anything that is related to Robocup@Home can always be discussed on the email list (cf. Section 1.4.1), but after the finalization of the rulebook cannot be taken into account or incorporated in the games until the next year.

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 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*. This means that using a preprogrammed sequence of movements or other actions to solve a task, without considering any sensor measurements as feedback in the process is *not allowed*. This includes for example navigation or manipulation by a timed sequence of motor commands.

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, garden, supermarket, restaurant etc. The scenario should change from year to year, as long as the desired tests can still be executed.

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 3.1.2).

All teams are invited to submit papers on related research at 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
  Manipulation is essential for almost any future home applications.
- Recognition of Humans
- Human Robot Interaction
  An aim of the competition is to foster natural interaction with the robot using speech and gesture commands.
- Speech recognition
  For intuitive interaction it is essential to come up with solutions that do not require headsets in the future.
- Gesture recognition
- Robot applications
  RoboCup@Home is aiming for applications of robots in daily life.
- Ambient intelligence
  Communicate with surrounding devices, getting information from the the Internet, e.g. Asking the robot about the weather, reading/writing emails.

Chapter 3

Rules

These are the rules for the 2011 competition.

3.1 Procedures before the competitions

3.1.1 Toward participation

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 Team Website and Team Description Paper

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 *Team Description Paper* (TDP) should at least contain the following sections:

- Name of the team
- contact information
- website
- team members
- description of the hardware
- description of the software

Preferably, it should also contain the following:

- innovative technology (if any)
- photo(s) of the robot
- focus of research/research interests
- re-usability of the system for other research groups
- applicability of the robot in the real world

The team description paper goes into detail about the technical and scientific approach, but the website should be designed for a broader audience. Both the website and the TDP have to be in English.

3.1.3 Qualification

During the *qualification process* a selection will be made according to the team data provided by the technical committee. To motivate the use of the new @Home Wiki, a special focus is put on the information the teams provide in the Wiki. So when entering relevant information in the Wiki (e.g. hardware and software related entries) make sure you put your team name next to it.

The evaluation criteria will include:

- Performance in previous competitions
- Team description paper
- Video
- Website
- Relevant Scientific contribution/publications
- Novelty of approach
- Contribution to RoboCup@Home League
  - Organization of events
  - Especially: Contribution to the RoboCup@Home Wiki and exchange of knowledge

3.2 Scenario

The RoboCup@Home competitions take place in a realistic home setting. It consists of inter-connected rooms such as a living room, a kitchen a bath room or bed room. There will be a designated area (e.g. a second room) which can be used for preparation.

3.2.1 Team area

The maximum number of people to register per team is unlimited, but the organization only provides space for *four* (4) persons to work at tables in the team area.

3.2.2 Walls, doors & floor

The indoor home setting will be surrounded by high and low walls. These walls will be built up using standard fair construction material (similar to what is used to build a fair booth) with neutral color, smooth surface and a minimum height of 60cm. A maximum height is not specified, but of course the audience still has to be able to watch the competition. Transparent glass elements could be used but it is unlikely at the moment. The walls will be fixed and will not be modified during the competition. There will be at least two entry/exit doors connecting the outside of the scenario which are used as starting points for the robots.

One can expect the floor of the arena and the doorways to the arena to be even. That is to say, there will be no significant steps or even stairways. However, minor unevenness such as carpets and transitions in floor covering between different areas must be expected.

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.

3.2.3 Furniture

Examples of previous @Home arenas are given in Figure 3.1. Please note that the actual arena will most likely look different.

The arena will be equipped with typical objects (furniture) that are not specified in quantity and kind. The minimum configuration consists of a small dinner table with two chairs, a couch, an open cupboard or small table with a television and remote control, some books in the cupboard and in the kitchen a refrigerator with some cans and plastic bottles inside. There will be at least two entrances to the scenario. At least one of the entrances will be a door with a handle (not a knob).

Since the robots should be able to function in the real world the scenario is not fixed and might change every day without further notice. Changes will influence the position of objects inside the arena. One hour before a test slot begins no *major* modifications will be made.

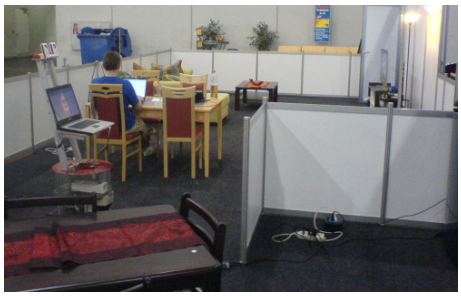
3.2.4 Predefined objects

Certain tests involve interaction with *predefined objects*. Figure 3.2 shows predefined objects used in previous competitions. The TC will compile a set of roughly 20 different objects. There are no restrictions on object size, appearance or weight. See Figure 3.2 for examples from previous competitions. At the beginning of the competition, each team chooses 10 objects from that list.

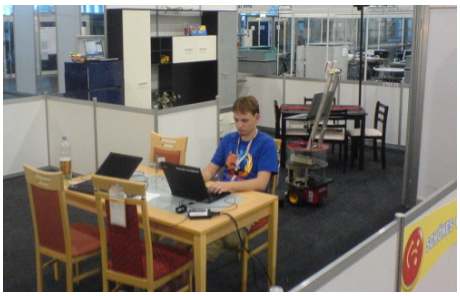
Whenever a test involves the use of a predefined object it is taken from this set. The TC makes the set of objects and their names available during the setup days.

In manipulation tasks, the objects will be positioned less than 15cm away from the border of the surface they are located at. There will be at least 5cm space to both sides of each object.

In a test which involves objects unknown to the robot, these may be taken from the set



(a) RoboCup 2006 Bremen - living room



(b) RoboCup 2006 Bremen - kitchen area

(c) RoboCup German Open 2007 Hannover

(d) RoboCup 2007 Atlanta

(e) RoboCup German Open 2008 Hannover

(f) RoboCup 2008 Suzhou

(g) RoboCup 2009 Graz

(h) RoboCup Japan Open 2010 Osaka

(i) RoboCup 2010 Singapore

Figure 3.1: Previous @Home arenas as example configurations

of predefined objects which the team did not choose.

(a) Predefined objects in RoboCup 2009

(b) Predefined objects in RoboCup 2010

Figure 3.2: Examples of predefined objects

3.2.5 Predefined locations

Some tests involve *predefined locations*. This may include places as well as certain objects such as 'plant', 'television', or 'front door'. The TC provides a list of these predefined locations before the beginning of the competition. Note that the positions are *not* necessarily fixed.

3.2.6 Predefined names

Some tests involve the *predefined names* of people. In such tests, a person interacting with a robot is given a name from a list of a certain amount of the predefined names. The TC provides the list before the beginning of the competition.

The following 10 names were used in RoboCup 2009 Graz.

> Jacob, Michael, Ethan, Joshua, Daniel, Alexander, Anthony, Emma, Isabella, Emily

Note that the total amount of names will be 20 in RoboCup 2011.

3.2.7 Rooms

Each room will be assigned a unique name. The TC provides a map of the scenario containing the names of all rooms before the beginning of the competition.

3.3 Robots

Robots that participate in the RoboCup@Home league need to be *autonomous* and *mobile*.

3.3.1 Number of robots

The maximum *number of robots* per team that can be registered for the competitions is *two* (2). Unless stated otherwise, one robot is allowed per test, but in the Open Challenge and the Finals two robots can be used simultaneously. For different tests different robots can be used.

3.3.2 Size and weight of robots

The dimensions of a robot should not exceed the limits of an average door, which is 200 by 70 cm. We do allow the registration of robots up to 200 by 80 cm, which is the average door size in some countries, but due to the international character of the competition we cannot guarantee that the robot will be able to go through the doors and participate. Please contact the organization if you have questions about this.

The weight of the robot and the pressure it exerts on the floor is limited by the local regulations for the construction of buildings which are used for living and/or offices where the competitions are being held.

Team members are responsible for moving the robot in and out the arena quickly. If the robot cannot move by itself, the team members must be able to transport the robot away with an easy and fast procedure.

3.3.3 Emergency stop button

Every robot has to provide an easily accessible and visible emergency stop button. 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 might ask to tape over the other buttons on the robot with colored tape. When pressing this button, the robot and any parts of it have to stop moving immediately.

3.3.4 Start button

Every participating robot has to provide a "*start button*" that can be used by the referee (or by team members) to start tests when needed (see also sec. 3.6.6).

The start button can be any "one-button procedure" that can be easily executed by a referee to start the robot. This includes:

- the release of the "emergency off" button
- an hardware button different from the "emergency off" one (e.g., a green button)
- a software button in a Graphical User Interface (either on the robot or on a remote PC connected with the robot)
- a key on the keyboard (either on the robot or on a remote PC connected with the robot)

The start button for a robot should be the same for all the tests and must be announced in the *robot registration* form and tested during the *robot inspection* procedure.

3.3.5 Appearance and safety of the robot

Robots should have a nice look. In particular, most of the robots internal hardware (electronics and cables) should be covered in an appealing way.

There may not be any loose cables hanging out of the robot. If may also not have sharp edges or other things that could severe people. The robot should not permanently make loud noises or use blinding lights.

3.3.6 Audio output

Either the robot or some external device connected to it should have a *speaker output plug*, which outputs the audio signal generated by the robot.

This will be used to connect the robot to the sound system so that the audience and the referees can hear and follow when the robot is talking.

3.4 External devices

Everything which is not part of the robot and is being brought into the arena by a team additionally is considered an *external device*. In general, external devices are not allowed during the competition unless presented and explained to the Technical Committee during the Robot Inspection. If a team wants to make sure that a certain external device is allowed, it is recommended to ask the Technical Committee far before the competition.

For the Open Challenge, the Demo Challenge, and the finals, external devices are allowed, still their use needs to be announced beforehand.

3.4.1 Wireless devices

Every team has to provide a list of all wireless devices they plan to use on site. This includes any analog or digital wireless microphones, bluetooth, headsets, walkie-talkies, and anything else that uses an RF signal to operate.

The list has to be provided to the Organizing Committee before the competition. The use of any wireless device not listed is strictly prohibited.

3.4.2 Artificial landmarks

Artificial landmarks and *markers* are not allowed.

3.4.3 Computing devices

External devices may also include computers used for decentralized computation or external sensors. External computers are allowed, but have to be inside the arena, i.e. not on its periphery.

3.4.4 Microphones

External microphones (also headsets) are allowed. A long-term goal is to integrate the microphones on-board. In some tests, the use of an *on-board microphone* is rewarded with an extra score.

3.4.5 Wireless network

For wireless communication, one WLAN Router will be provided using IEEE 802.11b standard (Max 11Mbit), another one using IEEE 802.11a. One channel will be provided for each 802.11a and 802.11b for RoboCup@Home. To avoid interference with other leagues if using WLAN in general, these routers and channels have to be used for communication only. It is not allowed to use the above or any other WLAN for personal use in the halls.

During the competitions, only the active team is allowed to use the WLAN Router and the channel. However, organizers cannot guarantee reliability and performance of wireless communication. Therefore, teams are required to be ready to setup, start their robots and run the tests even if, for any reason, network is not working properly.

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

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.

Stage I The first days of the competition will be called *Stage I*. All qualified teams can participate in Stage I. The tests in this stage can be done quite quickly and are not very complex. The *Open Challenge* will be done in Stage I so everybody can, and should, prepare for it.

Stage II Only the best *50% of teams* advance to *Stage II* which is being held within the last 2 days of the competition. Here more complex abilities or combinations of abilities are tested. The *Demo Challenge* will be held within Stage II.

Finals The best *five teams* from Stage II advance to the finals. In case there is no considerable score deviation between a finalist and a team not advancing to the finals, the TC may announce additional finalists.

3.5.2 Number of tests

In Stage I, the *maximum number of tests* that a team can participate in is *five out of five*.

In Stage II, the *maximum number of tests* that a team can participate in is *four out of four*.

None of the tests is mandatory, except for the Robot Inspection and Poster Session. However, teams have to indicate to the TC in which tests they participate. Otherwise, they receive a penalty (see sec. 3.7.1).

3.5.3 Schedule

The tests will be held in test slots of approximately two hours. A schedule for all teams is provided by the OC organizing access to the arena between competition time which can be used for preparation/calibration. One hour before a test slot, only the teams participating in that slot are allowed in the arena.

3.5.4 Score system

In Stage I (excluding the Open Challenge), the maximum total score per test is *1000 points*, unless specified otherwise in the test. In Stage II and the Open Challenge, the maximum total score per test is *2000 points*, unless specified otherwise in the test.

If the total score for a test is below zero, the team does not receive any points. An exception to this is the penalty for not attending (see sec. 3.7.1).

The total score of Stage I including the Open Challenge determines the teams that advance into Stage II. Then, the total score of Stage I and II determines teams advance into the finals.

Partial Score

All tests except for the Open Challenge are rewarded on a partial scoring basis. That is to say a team receives points for successfully passing a certain part of that test.

3.5.5 Open Challenge

Within Stage I the Open Challenge (OC) is being held. To participate in the Open Challenge the team has to participate in at least one other test in Stage I.

In the Open Challenge a team can demonstrate freely chosen abilities according to the goal and criteria of the league. The performance is evaluated by a jury that consists of the team leaders of all other teams. This evaluation will decide on the ranking.

The Open Challenge is described in Section 4.6 in detail.

3.5.6 Demo Challenge

Within Stage II the *Demo Challenge* (DC) is being held. The Demo Challenge is a challenge on a specific topic that is (re-)defined on a yearly basis. Teams can demonstrate their robots abilities according to the topic with some restrictions The Demo Challenge is described in detail in Section 5.4.

3.5.7 The Finals

The competition ends with the finals on the last day, where the five teams with the highest total score compete. The concept is the same as in the Open Challenge, but evaluation criteria of the jury are different. The jury will probably consist of people from various background, not only from robotics.

The demonstration in the finals does not have to be different from the one shown in the Open Challenge (if any). It does not have to be the same either.

3.6 Procedures during the tests

3.6.1 Safety first!

The speed of the robots should ensure safe operation. This means that the robot is not allowed to go faster than the local speed limits. During operation in an environment with humans it may not exceed a walking pace of humans (6 kph, 3.7 mph).

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. 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*.

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

During a test, the maximum number of team-members allowed inside the arena is *two* (2), unless stated otherwise. During the setup of a test, in the Open Challenge, in the Demo Challenge and in the Finals there is no limitation on the amount of persons allowed in the arena. During a test, one team member *must* be available to host the event.

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
- 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)

- not trying to make other robots fail on purpose

Disregard of this rule can lead to disqualification for a test or even for the entire competition.

3.6.4 Robot autonomy

During a test, the participants are not allowed to make contact with the robot, unless it is in a "natural" way. This means that gestures and speech are allowed but remote control or touching buttons on the robot are not!

The idea of *autonomy* is that only general instructions can be given, such as "Go to the kitchen". Anything that resembles direct control, such as "lift gripper, stop, forward 1.2, ..." instead of "get the red can out of the refrigerator" is not in accordance with the idea of autonomy.

3.6.5 Traffic rules

If two robots encounter each other, they both have to actively try to avoid the other robot. If a non-moving robot is blocking the path of another robot, the non-moving robot is removed and the team may call for a restart (if there is one left). In this context, "moving" refers to any kind of motion required in the test. That is, 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.

In any case, if a path is blocked (could be a robot or that the furniture is moved) the robot has to find a different route. A robot which is not going for a different route within a reasonable amount of time (e.g., one minute) may be removed by the referees/TC and the team can get a restart (if there is one left).

Robots are allowed to gently touch objects, items and humans. They are not allowed to crash into something. But since the "safety first" rule from sec. 3.6.1 supercedes all other rules, it is better that the robot does not touch anything. The OC/TC/EC and the RoboCup Trustees all have the right 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. In any case, if a robot crushes into something during a test, the robot is directly stopped.

3.6.6 Start signal

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.

If the robot is not able to detect that the door has been opened, it can still be started using the start button (see sec. 3.3.4). However, the team receives a penalty for doing this (see sec. 3.7.2).

In case that the start procedure does not work at all, the team can call for a restart and fix it, within the time allowed for the test.

3.6.7 Entering and leaving the arena

Unless stated otherwise, the robot has to autonomously enter and leave the arena through the open entrance/doorway. Remote control of the robot is forbidden.

3.6.8 Gestures

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

- The teams define the hand gestures by themselves.
- Gestures should not involve more than the movement of both arms. This includes e.g. expressions of sign language or pointing gestures.
- If a volunteer is supposed to operate the robot, the gesture commands to be used need to be specified by the team to the referees as well as the volunteer before the test starts.
- A speech command may be used to set the robot into a "receive gesture mode".

3.6.9 Referees

Two team members from two different teams – not from the team which is currently performing – and a member of the TC or OC are the *referees* for each test. The referee from the TC/OC acts as a main referee. Not showing up for refereeing will result in a penalty of 500 points for the referees team and will be remembered for qualification decisions in future competitions.

3.6.10 Moderator

A general aim of @Home is to explain our motivation, research and activities to the public audience. Therefore, where applicable, every test in the competition is commented by a moderator. So, for each regular test (not for Introduction, Open Challenge, Demo Challenge and Finals), the teams have to provide a moderator for the tests they are participating in. For competitive test (test in which two teams directly compete against each other) the moderation has to be done by the two teams together.

The moderator has to:

- explain the rules of the test
- comment on the performance of the teams
- not interfere with the performance
- speak in English

3.6.11 Time limits

All the tests have certain *time limits*. The time limit for each test includes setup time. After the period is over, the team has to immediately leave the arena. Partial credits (cf. Section 3.5.4) are awarded for the robot's performance only within the given time period.

Stage I

The time limit for each test in Stage I is *5 minutes* unless stated otherwise in the test description.

Stage II

The time limit for each test in Stage II is *10 minutes* unless stated otherwise in the test description.

3.6.12 Restart

A team has the opportunity to request one restart during a test. Although the test is restarted the time continues and is not restarted.

With a restart, the amount of points is the average of the first and second run if and only if in the second run the score is lower than in the first run, otherwise the score of the second run counts.

3.7 Special penalties, bonuses and awards

3.7.1 Penalty for not attending

If a team has registered and is scheduled for a test but can not participate in that test for any reason, the team leader has to announce this at least 15 minutes before the test slot begins. Otherwise there will be a penalty of *-500 points*. If a team is not present at the start position when their scheduled test starts, the team is not allowed to participate in this test anymore.

3.7.2 Penalty for using start button

If the start signal for a test is the opening of the door (see sec. 3.6.6), and the robot is started using the start button, the team receives a penalty of *-50 points*.

3.7.3 Bonus for outstanding performance

For every regular test in Stage I and Stage II (excluding Open Challenge, Demo Challenge and the Finals), the @Home Technical Committee can decide to give an extra bonus for *outstanding performance* of up to 10% of the maximum test score. 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. If a team thinks that it deserves this bonus, it should announce (and briefly explain) this to the Technical Committee beforehand. It is the decision of the TC if (and to which degree) the bonus score is granted.

3.7.4 Innovation award

To honor outstanding technical and scientific achievements as well as applicable solutions in the @Home league, a special innovation award is being given to one of the participating teams. Special attention is being paid to making usable robot components and technology available to the @Home community.

After the Open Challenge, the executive committee members from the RoboCup@Home league nominate a set of candidates for the award. The winner is determined by election of the Technical Committee. A TC member whose team is among the nominees is not allowed to vote.

Chapter 4

Tests in Stage I

4.1 Robot Inspection and Poster Session

The robot has to register itself and get approval to participate in @Home. The team has some time for a poster presentation and answering questions.

4.1.1 Focus

The purpose of this test is for the teams to get to know each other and for the TC to test the safety of operating the robot.

The test focuses on speech synthesis, articulation, presentation and appearance.

4.1.2 Task

The description is for two robots, but of course also only one robot can register in the case of using one robot in the competition.

In the scenario, at a table, there is a delegation of the Technical Committee (TC). The robots have to autonomously approach the table, such that they are facing it from a distance of less than 2 meters. Then, the robots have to register themselves. One of the robots may do the registration for both, which includes a spoken introduction (state the name of the team and the name of the robot) and optionally handing over the registration form to the TC. The registration should not take more than 2 minutes (per robot). The robot(s) are then inspected by the TC (for fulfilling the requirements of the competitions, e.g., having an emergency button).

During the inspection of the robot, the team leader gets a maximum of five minutes for a poster presentation (research focus, scientific contribution etc.). Team leaders from the other teams can ask questions (Q&A). If the registration of the robots – including going to the registration desk – takes longer than 2 minutes per robot, the time for the poster session is reduced.

The setup is as follows: The robot enters through door A, moves to the registration desk, and introduces itself. After being told so by the TC delegation, a team member commands the robot(s) the leave the arena through door B. This command is not restricted to speech,

pressing a button is fine. While leaving the arena the emergency button will be pressed. In case the robot does not stop immediately, it does not pass the inspection.

The inspection by the TC and the poster presentation by the team happen simultaneously.

4.1.3 Remarks

There is no fixed start signal in this test.

Both the location of the registration desk as well as the doors for entering and leaving the arena will be announced by the OC at least two hours before the test starts.

A team has to be ready to start immediately after the previous team finishes. After the previous team has finished, the next robot starts moving to the registration desk. If the total time is exceeded with more than 1 minute, less score is rewarded.

The evaluation of posters will be done by the team leaders (that is, *ALL team leaders* need to attend RIPS and evaluate the poster presentation of the other teams). Evaluation is done by filling out a score sheet, giving points from 0 to 10 for the following criteria: (score sheets are distributed by the OC)

- Quality of appearance of the poster
- Quality of the poster content
- Scientific value
- Poster presentation and Questions

The TC will inspect the participating robots to see whether they comply with the rules in sec. 3.4, checking in particular:

- robots size and weight
- presence and easy accessibility of the "emergency stop" button
- presence of the "start button"
- robot speaker system (plug for RF Transmission)
- use of external devices (including wireless network)
- manipulation constraints
- appearance of the system

Every robot has to get approval to be able to participate. If the robot does not succeed for the registration, it is the responsibility of the team to get the approval. No approval means no participation!

4.1.4 Referee Instructions

The referee has to make sure the time limit is not exceeded.

4.1.5 OC Notes

2h before test:

Specify and announce which doors will be used as entry door and exit door.
Specify and announce the location of the registration desk.

Any time before the test:

Prepare and distribute registration sheets (with manipulation heights/locations, manipulable objects, external devices etc., place for notes and signatures of TC and team leader).

Prepare and distribute poster session evaluation sheets.

After the test:

Prepare (and give to the TC) sheets with the following matrices:

- Teams → Objects:
  for easy lookup which objects can be manipulated by which team
- Teams → Locations:
  for easy lookup which locations can be used for manipulation for which team

4.1.6 Score Sheet

The maximum time for this test is *7 minutes* for one robot and *9 minutes* for two robots. If the time limit is exceeded, the total score in this test is limited to 500 points.

A non-functioning robot can be registered by a team member.

For the evaluation of the posters, every team leader gives up to 10 points for each poster presented.

Action	**Score**
Registration	
Non-autonomous registration	*100*
Autonomous registration (one robot)	*500*
Autonomous registration (two robots)	*2 × 250*
Neat Appearance	
No wires hanging out of the robot, e.g. no functional wire has to be tied to the robot, no duct-tape, internals covered, etc.	*200*
Poster session	
Arithmetic mean of scoring from evaluation sheets × 30	*300*
Special penalties & bonuses	
Not attending (see sec. 3.7.1)	*-500*
Outstanding performance (see sec. 3.7.3)	*100*
Total score	*1100*

4.2 Follow Me

The robot has to safely follow an unknown person through a dynamical environment.

4.2.1 Focus

This test focuses on tracking and recognition of an unknown person, multi-modal interaction and safe navigation in an unknown environment.

4.2.2 Task

The test takes place outside the arena, for example in a supermarket. A "professional" operator is selected by the TC to test the robot. This test is probably performed in parallel, implying that there are multiple "professional" walkers.

Before the test, the operator stands at least 3 meters away from the robot. When the test starts, he goes to the robot and tells it to follow him. The robot has to announce when it has finished calibrating and starts following the operator. It can also give the operator instructions on what to do during the calibration.

During the remaining time, the robot has to follow the operator on a predefined course and pass several tests until it surpasses the finish line.

The operator walks with his back towards the robot at a regular slow walking speed and waits for the robot if it is too slow, but never walks back except for interacting with it. The robot has to keep a distance of at least one meter to the operator, unless the operator walks towards it.

There are 4 predefined checkpoints throughout the course. At each checkpoint, a specific action has to be performed. If the robot fails in completing one of the tasks, the test ends.

Checkpoint 1: Temporary occlusion A second person passes by in between the robot and the operator, walking slowly. After that, the operator resumes walking and the robot has to follow him.

Checkpoint 2: Tracking from the distance The operator tells the robot to stop and wait. The robot then has to stay at its position without moving for 10 seconds. It has to announce when the 10 second period starts. The operator then walks 3 meters away from the robot in a way that there are no objects in between the robot and him. When the 10 seconds have passed, the robot has to approach the operator again and continue to follow him.

Checkpoint 3: Recognize owner The operator tells the robot to stop. He then goes to some location where he is completely hidden from the robot. Then the operator and another person (which did not appear before to the robot) walk towards the robot. They stand approx. 1 meter apart from each other and approx. 1.5 meters in front of the robot. The robot has to recognize which of the two is the operator and follow that person.

Checkpoint 4: Finish line All parts of the robot which are touching the ground must completely surpass the finish line.

4.2.3 Remarks

The start signal in this test is pushing the start button (see sec. 3.3.4).

The team may tell the operator how to operate the robot and can hand him a note or something similar on this topic. This includes for example speech and gesture commands and information about the calibration procedure. They have 2 minutes to do that before the test starts.

The gesture commands must also be specified by the team to the referees before the test starts. They must confine with the rules in sec. 3.6.8. If they do not confine with the rules, only speech commands may be used.

If a person from the audience interferes with the robot in a way that makes it impossible to solve the task, the team may repeat the test immediately.

4.2.4 Referee Instructions

The referees need to

- select walkers and show them the path to walk on.
- define where the check points are located.
- ask the team if it will be using gestures
- if the team uses gestures, check if they comply with the rules (see sec. 3.6.8)
- detect whether a robot touches something.
- detect if the robot is coming too close to the operator.
- check if the team successfully fulfils the task at each checkpoint
- take special care of not interfering with the robots.

4.2.5 Score Sheet

The maximum time of the test is *8 minutes*, including calibrating on the operator.

Action	**Score**
Checkpoint 1: Temporary occlusion	
Successfully resume following the operator	*100*
Checkpoint 2: Tracking from the distance	
Understanding the user command	*50*
Bonus for using a gesture	*100*
Waiting a minimum of 10 seconds and then *finding and following the operator*	*100*
Checkpoint 3: Recognize owner	
Understanding the user command	*50*
Bonus for using a gesture	*100*
Recognizing and following the operator after he returns	*200*
Checkpoint 4: Finish line	
Crossing the finish line	*200*
No touching	
Reaching all 4 checkpoints and *not having touched any object or human* in the scenario	*100*
Special penalties & bonuses	
Not attending (see sec. 3.7.1)	*-500*
Outstanding performance (see sec. 3.7.3)	*100*
Total score	*1100*

4.3 Go Get It!

Two robots (from different teams) simultaneously have to find and retrieve objects.

4.3.1 Focus

This test focuses on object detection, recognition and manipulation as well as navigation and systematic searching in a dynamic environment.

4.3.2 Task

Two teams are competing simultaneously. Their robots start at different entrances to the scenario. Two rooms of the scenario are used for this test. In each one, there are four objects randomly spread around. The objects are selected from the list of *predefined objects* (see sec. 3.2.4). Of those four objects, two are placed on the floor and two on a table or something with a similar height in an upright position.

There will also be four other objects of similar size in each room, which are not on the list. Thus, these may not be retrieved by the robot. Two will be placed on the floor, the other two at table-height.

Each team is randomly assigned a different room (e.g. by throwing a coin).

The procedure is as follows:

Entering After the test has started, the robots enter the scenario and stop one meter from the door.

Specifying rooms Two referees simultaneously tell the robots to which room they should go. No additional information will be given to the robot.

Retrieve object The robots go to their rooms and have to retrieve one of the objects on the list. Before grasping it, it has to identify the object. This can be done by either speech, display or any way that the referees can check what the robot has recognized.

Leave The robots have to leave the arena through the door which they used to enter the scenario.

Points can be scored for finding the object, for carrying it back to the start location and handing it to the operator.

4.3.3 Remarks

The start signal in this test is the opening of the door (see sec. 3.6.6).

The two rooms to be used in this test will be specified by the TC before the competition (see 3.2.7).

To all locations in the scenario, there will always be some path for reaching it, without any object blocking it.

The TC selects 4 of the 10 *predefined objects chosen by the team* (see section 3.2.4).

For each test run, 4 other objects from the list of *predefined objects* are selected as "unknown objects" in both rooms.

The object identified does not have to be the same as the one grasped. If the robot tries to grasp one of the unkown objects, the team can not receive points for grasping and bringing a correct one afterwards. Multiple tries to grasp objects are allowed, as long if all of them are from the list of known objects.

Driving over the objects on the floor is not allowed, except for minor collisions.

There are two robots navigating in the environment at the same time. Thus, the rules described in sec. 3.6.5 apply.

If one of the robots enters the room of the other robot for more than 30 seconds, or is interfering with the other robot, the robot must be removed from the scenario and cannot continue with this test.

In this test, a restart is not allowed.

4.3.4 Referee Instructions

The referees need to

- place the eight objects in each room, including the ones that may not be retrieved, on a flat surface and less than 15cm away from its border. They have to be placed in a way that they are visible and can be manipulated from some point in the environment.
- pay special attention that the robots obey the traffic rules (see sec. 3.6.5)
- detect if a robot enters the wrong room.

4.3.5 Score Sheet

The maximum time for this test is *5 minutes*.

All points can only be given once in this test. If the robot identifies an object wrongly, it cannot receive the points for identifying the correct object.

If one of the robots *enters the room of the other robot* for more than 30 seconds and is not trying to return to its own room or interferes with the other robot, then the test is finished for this robot and it has to be removed from the area.

Action	**Score**
Navigating to the room	
Successfully reaching the correct room	*200*
Identifying an object	
The robot correctly indicates which of the (known) objects it has identified. The robot has to be facing it and be within a distance of max. 50 cm.	*200*
Grasping the object	
Grasping the object and successfully lifting it up to at least 5 cm for more than *10 seconds*	*200*
Handing to user	
Successfully returning to the operator and handing the object to him/her. The operator has to be in the same place as he/she was when telling the robot where to go.	*300*
Leaving the arena	
Autonomously leaving the arena within the time limit	*100*
Special penalties & bonuses	
Not attending (see sec. 3.7.1)	*-500*
Using start button (see sec. 3.7.2)	*-50*
Outstanding performance (see sec. 3.7.3)	*100*
Total score	*1100*

4.4 Who Is Who

A robot should be able to autonomously recognize persons in an unknown environment. Without manual calibration, a robot will have to introduce itself to a group of people, ask for their names, memorize them and recognize the persons when meeting them again. Before the test a list with 20 English names is published which the robot should be able to recognize.

4.4.1 Focus

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

4.4.2 Task

Before the test starts, the arena is reconfigured. If the robot attempts to leave the arena by opening a door autonomously, the team should announce this to referees beforehand.

Entering the scenario The robot enters the arena through the door and stops next to it.

Introduction of guests Two persons enter through the door and introduce themselves to the robot, one by one. They do this while standing in front of the robot. The robot can give instructions to the persons on what to do during this learning phase. It must not involve touching any part of the robot. The persons are assigned names from the list. After the person has told the robot its name, it has to announce which name it has understood. The robot may ask the person to repeat its name if it hasn't understood it correctly without losing points. If the robot misunderstands the name during this phase, it can still use the wrong name to identify the person later. This is the understanding names part.

Searching guests The two persons go to another room, one sits down and one stands. In this room, there are two other persons which are known to the robot, e.g. members of its team, of which one is sitting and one standing. There is also one person standing in the room which is not known to the robot. All persons do not move around. They are either looking at the robot or looking straight. When told to do so by an operator, the robot goes to the room and starts looking for guests.

Identifying persons When the robot finds a person, it has to approach it and state that it has found a person (identification part). It then has to recognize the person by stating its name or state that the person is unknown (recognition part). The announcement must be done by facing the person.

Leaving the arena When the robot has found all known persons or decides to stop searching, it leaves the arena through the entry door. The robot may leave the arena by opening the closed door autonomously.

4.4.3 Remarks

The start signal in this test is the opening of the door (see sec. 3.6.6).

During the test, only the robot and the guests are inside the scenario. The door opener will stay behind the door until the robot has left the room. Referees and other personnel will be outside the scenario.

The robot may ask a person to look at it for identification when standing next to him/her. However, if there is no person, it receives the penalty for incorrect human detection.

The room where this test takes place will be announced beforehand.

4.4.4 Referee Instructions

The referees need to

- select the people and their names before the test starts
- select the location for each person to stand before the test starts.
- always stay behind the robot
- write down the names of the two previously known persons and the names the robot assigns during the introduction
- close the door after the robot enters the arena if the team announces that the robot attempts to leave the arena by opening the door

4.4.5 Score Sheet

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

When using an onboard microphone, the distance between the person speaking and the robot has to be at least *50 cm*.

Action	**Score**
Receive guests	
Understanding name	*2 × 25*
Using onboard microphone	*2 × 100*
Searching guests	
Correctly identifying a person as a human *(1 × per person)*	*5 × 50*
Correctly identifying a known person by its name	*4 × 75*
Correctly indicating that a person is unknown	*100*
Confounding one of the persons *(identifying him/her by the wrong name)*	*-100*
Incorrectly identifying something as a human	*-150*
Leaving the arena	
Autonomously leaving the arena within the time limit	*100*
Autonomously opening the door before leaving	*250*
Special penalties & bonuses	
Not attending (see sec. 3.7.1)	*-500*
Using start button (see sec. 3.7.2)	*-50*
Outstanding performance (see sec. 3.7.3)	*100*
Total score	*1350*

4.5 General Purpose Service Robot I

This test evaluates the abilities of the robot that are required through out the previous tests in Stage I. In this test the robot has to solve multiple tasks upon request. That is, the test is not incorporated into a (predefined) story and there is neither a predefined order of tasks nor a predefined set of actions. The actions that are to be carried out by the robot are chosen randomly by the referees from a larger set of actions.

The test lasts 5 minutes.

4.5.1 Focus

This test particularly focuses on the following aspects:

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

4.5.2 Requirements

Required in this test are:

- abilities from stage I forming a set of actions A (e.g., following a person, finding a person, grapsing and delivering objects),
- a set of objects O (the same set as used as in the other tests),
- a set of locations L (the same set as used as in the other tests).

4.5.3 Task

The robot enters the arena by driving to a specified location. This location is at least five meters away from the place of entering the arena. If a restart is requested by the team, the robot has to leave the arena and start again from the outside. It is then given a command containing three tasks. Each task assignment contains an action ($a \in A$) and depending on the respective action an object ($o \in O$) and/or a location ($l \in L$). In contrast to L and O, the set of actions is not given beforehand. Instead teams should identify the abilities from stage I by themselves (and find synonyms for that). That is, L and O are known in advance (provided at the first setup day), A has to be "found out" by the teams (e.g. taken from freely available ontologies, synonym searches etc.). The only restriction for the actions is that we are going to use common synonyms (like "go to", "move to", "drive to", and "navigate to" to describe navigation).

Assigning Commands

The speaker assigning the tasks to the robot can be chosen by the team. The command is generated by a program provided by TC. The speaker has to repeat the exact sentence

that was given to him/her. If the robot asks questions to retrieve more information, the referees/TC will tell the speaker what exactly to answer.

Command Categories

In Stage I only one category of complexity will be used:

Cat. I Understanding complex commands
(sequence of three commands)

Procedure

The computer generates a complex command for the user to tell the robot. The complex command, which is an English sentence, has to be read *exactly* to the robot. Not reading it exactly counts as a failure. If the robot does not understand the sentence after 3 tries, or the sentence is not read correctly, a restart is allowed. Then a new sentence is generated and the team can try it again. A restart also means that only half of the amount of points can be scored.

4.5.4 Actions and Categories

Category I Understanding complex commands:
Example: *"Move to the living room, get the cup and put it one the kitchen table"*. As described above, one command consists of three actions. Every action might involve an object and a location. In case the robot has not fully understood the command, it might ask for

1.) repeating the complete sentence

2.) give information on one specific part (e.g., the robot says that it has understood to go the living and to get cup but has not understood what to do with the cup). What is not allowed is to ask for the first command, for the second, etc.

4.5.5 Remarks

The start signal in this test is the opening of the door (see sec. 3.6.6).

Since the score system in this test involves a subjective evaluation of the robot's behavior, the referees are assisted by TC members.

4.5.6 Referee Instructions

The place where the command is given is at least five meters aways from the entry. In case of a restart, the robot has to re-enter the arena. The referees/TC members will tell a team member the command. The team member has to assign the command to the robot exactly as it was given to him.

4.5.7 Score Sheet

The maximum time for this test is *5 minutes*.

Action	**Score**
Category I	
Performing the first command correctly	*300*
Performing the first and second command correctly	*300*
Successfully solving the complete task	*400*
Special penalties & bonuses	
Not attending (see sec. 3.7.1)	*-500*
Using start button (see sec. 3.7.2)	*-50*
Outstanding performance (see sec. 3.7.3)	*100*
Total score	*1100*

4.6 Open Challenge

During the *Open Challenge* (OC) teams are encouraged to demonstrate the best of their robots' abilities.

4.6.1 Focus

This test focuses on the demonstration of new approaches/applications, human-robot interaction and scientific value.

4.6.2 Task

The Open Challenge consists of a demonstration and a question part. All teams have to provide *one* person (preferably the team-leader) to follow and evaluate the entire Open Challenge. Not providing a person results in no score for this team in the OC. For the demonstration *only two slides* are allowed. The focus should be on the demonstration. When the team enters, it has *three minutes* for the setup. Then the team has maximum *five minutes* for the demonstration. When the demonstration is finished there is another *three minutes* where the team answers questions and the next team is setting up their demonstration. A wireless microphone and a video projector will be available to the teams. The video projector can only be used to show your affiliation (team name, institute, country, ...) and for the internal workings of the robot during the demonstration. It is mandatory to make a handout of you presentation of 1 or 2 pages, stating at least you team name and a short description of the demonstration at the Open Challenge and a recent picture of the robot. The demonstration and the questioning influence the score.

Changes to the Environment

For the Open Challenge teams are allowed to make modifications to the environment as they like under the condition that they are reversible and the team leaves the arena in the *very same* condition they entered it (i.e. revert all modifications made). The changes and their reversion have to be made within the total time given.

4.6.3 Remarks

There is no fixed start signal in this test.

4.6.4 Score System

The score is determined by the other team leaders. This person has to be present all the time, either in the scenario or in the designation part on the tribune. Acting against that can be punished by disqualification of the team from the OC.

For each evaluation criterion (see below) a maximum of *10 points* is given per team leader.

Evaluation Criteria

The evaluation of the jury is based upon the desired abilities described in Section 2.10 and the following criteria:

- Overall demonstration
- Human-robot interaction in the demonstration
- Autonomy in demonstration/presentation
  Robot autonomy during the demonstration and presentation. Presentation by robots is highly evaluated.
- Realism
  Usefulness for daily life(Can this robot become a product?).
- Novelty and contribution
  Scientific contribution and contribution to the community.
- Difficulty and success of the demonstration

Normalization

The points given by each team leader are multiplied by a factor of $\frac{200}{6}$ to receive a maximum of *2000 points* per team leader. In case of 20 or more teams, the two highest and the two lowest scores do not count and N = 5. In case of 10 to 20 teams, the highest and the lowest scores do not count and N = 3. The total score for each team is then calculated by

$$\frac{\sum \text{team-leader-score}}{\text{number-of-teams} - N}$$

Chapter 5

Tests in Stage II

5.1 Enhanced Who Is Who

The robot has to memorize previously unknown persons, detect if one of them is calling it by waving at it, and deliver a drink to one of the persons.

5.1.1 Focus

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

5.1.2 Task

Before the test starts, the arena is reconfigured.

Entering the scenario The robot enters the arena through the door and stops next to it.

Introduction of guests Three persons enter through the door and introduce themselves to the robot, one by one. They do this while standing in front of the robot. The robot can give instructions to the persons on what to do during this learning phase. It must not involve touching any part of the robot. The persons are assigned names from the list. After the person has told the robot its name, it has to announce which name it has understood. The robot may ask the person to repeat its name if it has not understood it correctly without losing points. If the robot misunderstands the name during this phase, it can still use the wrong name to identify the person later.

Go to other room The three persons go to another room and stay there, two standing and one sitting. There are also two persons in the room which are not known to the robot, one standing and one sitting. The persons do not move around. They are either looking at the robot or looking straight. When told to do so by an operator, the robot also goes to that room.

Calling the robot One of the known standing persons will try to get the attention of the robot. He can do this by lifting his arm and waving with his hand or by calling

it by voice. The robot has to approach that person. The distance from the robot to the person must not exceed one meter. If the robot fails to approach the person within 2 minutes or if the team decides so, the person approaches the robot and stands in front of it.

Ordering There will be three different drinks. The person will tell the robot to bring him/her one of the drinks and the two remaining drinks to the two other known persons, stating which person wants which drink. There will be a predefined position in another room where the drinks will be positioned. Drinks can be in the form of an (empty) cup, a bottle (may be empty), a can (empty or not) or any other object that the robot can carry and is a container-like object that can (theoretically) hold liquids.

Change places At any time, all persons in the room move by max. 2 meters from their original designated (by the TC/referees) starting position. This is restricted in the sense that they are not allowed to change their body posture. So a sitting person remains sitting, and a standing person remains standing.

Delivering the drink The robot has to go to the other room and get the drinks. When the robot returns, it has to find the correct persons and give the respective drinks to them. It can do so by going to the other room multiple times.

Leaving the arena After delivering all three drinks, the robot has to leave the arena.

5.1.3 Remarks

The start signal in this test is the opening of the door (see sec. 3.6.6).

During the test, only the robot and the guests are inside the scenario. The door opener will stay behind the door until the robot has left the room. Referees and other personnel will be outside the scenario.

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. It can also decide to skip this part.

The robot may ask a person to look at it for identification when standing next to him/her. However, if there is no person, it receives the penalty for incorrect human detection.

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.

The room where this test takes place will be announced beforehand.

5.1.4 Referee Instructions

The referees need to

- select the people and their names before the test starts
- select the location for each person to stand or sit before the test starts.
- define which person will be waving at the robot
- define which drinks will be delivered to which person

- define where the drinks will be standing, in accordance with the limitations of the robot
- write down the names the robot assigns during the introduction.
- always stay behind the robot

5.1.5 Score Sheet

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

Action	Score
Receive guests	
Understanding name	*3 × 25*
Using onboard microphone	*3 × 100*
Taking the order	
Finding the calling person and asking it for its order	*250*
Asking the wrong person or something that is not a person for its order	*-150*
Grasping drinks	
Grasping a drink and successfully lifting it up to at least *5 cm* for more than *10 seconds*	*3 × 200*
Delivering drinks	
Delivering the correct drink to the person which ordered the drinks	*200*
Delivering to the other standing person	*225*
Delivering to the sitting person	*250*
Leaving the arena	
Autonomously leaving the arena within the time limit	*100*
Special penalties & bonuses	
Not attending (see sec. 3.7.1)	*-500*
Using start button (see sec. 3.7.2)	*-50*
Outstanding performance (see sec. 3.7.3)	*200*
Total score	*2200*

5.2 General Purpose Service Robot II

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

5.2.1 Focus

This test particularly focuses on the following aspects:

- No predefined order of actions to carry out (to slowly get away from state machine-like behavior programming)
- Increased complexity in speech recognition (possible commands are less restricted in both actions/operators and arguments/objects, commands can include multiple objects, e.g., "put the mug on the kitchen table")
- Testing how much the robot understands about the environment (towards (high-level) reasoning)

5.2.2 Requirements

Required in this test are:

- abilities from stage I forming a set of actions A (e.g., following a person, finding a person, grapsing and delivering objects),
- a set of objects O (the same set as used as in the other tests),
- a set of locations L (the same set as used as in the other tests).

5.2.3 Task

The robot enters the arena by driving to a specified location. It is then given commands. Each task assignment contains an action ($a \in A$) and depending on the respective action an object ($o \in O$) and/or a location ($l \in L$). In contrast to L and O, the set of actions is not given beforehand. Instead teams should identify the abilities from stage I by themselves (and find synonyms for that). That is, L and O are known in advance (provided at the first setup day), A has to be "found out" by the teams (e.g. taken from freely available ontologies, synonym searches etc.). The only restriction for the actions is that we are going to use common synonyms (like "go to", "move to", "drive to", and "navigate to" to describe navigation).

Assigning Commands

The speaker assigning the tasks to the robot can be chosen by the team. The command is generated by a program provided by TC. The speaker has to repeat the exact sentence that was given to him/her. If the robot asks questions to retrieve more information, the referees/TC will tell the speaker what exactly to answer.

Command Categories

The are two categories in this test, differing in complexity and scores:

Cat. I Action with incomplete information
(robot needs to ask questions to obtain full task specification)

Cat. II Action with erroneous information
(robot has to utter what went wrong and why)

Procedure

Every team can do up to two tasks in one instance of the General Purpose Test. Before every task instance, the team may choose the category. That is, it is not only possible to do both categories, but also to repeat a category. The final score for the General Purpose test is the sum of the maximum scores for each category, i.e., $\max(\text{Cat. } 1) + \max(\text{Cat. } 2)$. Here it is referred to the score sheet. It is, however, not allowed to tell the robot from which category the next task is coming. That is, the user (selected by the team) is only allowed to repeat sentences giving by the task generating program or the referee/TC members in the arena.

5.2.4 Actions and Categories

Category I Action with incomplete information:
The robot gets a command that does not include all the information being necessary to accomplish the respective task. In order to do that, we are going to classify objects and locations. That is, in contrast to the object and locations lists from last years, every instance on this list will be assigned to a class. For example, we might have object instances “coke”, “fanta” and “sprite” all belonging to the class “drink” while the instances “chips” and “noodles” belong to the class “snack”. The same will be done for the locations, e.g., “dinner table” and “kitchen table” belonging to the class “table”. The actual task assignments will then be underspecified by, for example:

1.) only giving the class but not the actual instance or

2.) not giving the location but only an object.

Another example would be to not tell the robot where a specific object is located. In any case, the robot might ask up to five questions to get more

information about the task. However, the robot might also accomplish the task without asking any question. If, for example, the task is to get a drink, the robot might search the environment for any instance of the class drink (incl. grasping and delivering it), to get the score for successfully accomplishing the test. However, asking reasonable questions about the task will give more points.

Category II **Action with erroneous information:** In this category, the given command contains erroneous information. One might, for example, command the robot to get the red cup from the kitchen table although there is no red cup at the kitchen table. The robot should then clearly state that

1.) it was not able to bring the red cup, because

2.) there was no red cup on the kitchen table.

There is a bonus of 100 points for giving a solution to the problem or to completely solve the test by e.g.:

1.) telling the user that there was another cup (the blue one) one the table,

2.) stating the problem as above but retrieving the blue cup (bringing an object of another class would be wrong here)

3.) searching the environment for the red cup (that is on the dinner table), finding and delivering it.

5.2.5 Remarks

The start signal in this test is the opening of the door (see sec. 3.6.6).

Since the score system in this test involves a subjective evaluation of the robot's behavior, the referees are assisted by TC members.

5.2.6 Referee Instructions

For both actions/tasks that are assigned to the robot, the team chooses the desired action category and the referees/TC members instruct the user what to tell the robot.

5.2.7 Score Sheet

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

Action	**Score**
Category I	
Asking correct/reasonable questions (to require missing information)	*300*
Solving half of the task or more (showing that the robot has understood the command and works on the test) ***and***	*200*
Completely solving the task	*300*
Category II	
Showing that the robot has understood the command and works on the test	*200*
Solving the task up the point where the error occurred	*200*
Indicating that a problem has occurred while executing the task	*200*
Returning to the user and explaining what went wrong	*200*
Giving an alternative solution to the problem	*200*
Total Score	
$\max(\text{Cat. I}) + \max(\text{Cat. II}) = 1800$	
Special penalties & bonuses	
Not attending (see sec. 3.7.1)	*-500*
Using start button (see sec. 3.7.2)	*-50*
Outstanding performance (see sec. 3.7.3)	*180*
Total score	*1980*

5.3 Shopping Mall

5.3.1 Focus

The focus of this test is mobile manipulation in a real environment, ideally a shop or supermarket (in the following "the shop". 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.

5.3.2 Task

Guide Phase: A robot is guided through a shop (by one of the team members). Starting from some fixed entry, e.g., the supermarket's main entrance, the user shows the robot *four locations*. At each location the user guides the robot to a particular shelf and tells it which *object* can be obtained from that shelf. The objects are taken from the set of (manipulable) objects (as specified by the team). There is only one type of object from the list in each shelf. Note that there can be many objects of that type, e.g. a row of soup cans of the same type as the one that has to be grabbed. However, there will be at least one object of the correct type which is positioned such that it can be manipulated. The operator is allowed to point at the object which can be manipulated from a distance of at least 50 cm. There is no constraint on what kind of pointing gesture to use, e.g., it can be by pointing with a finger or by just looking at it.

After reaching all four locations, the user guides the robot to a (predefined) *checkout* location.

Manipulation and Navigation Phase: At the *checkout*, the user commands the robot to get objects from the shelves. In total, three out of four objects need to be retrieved from the corresponding shelves and delivered to the user waiting at the checkout. Consider, for example, you have forgotten something and want the robot to get it for you.

After retrieving all three objects, the robot is commanded to return to the starting position.

There is a maximum of 10 minutes for this test.

5.3.3 Remarks

The start signal in this test is pushing the start button (see sec. 3.3.4).

The person guiding the robot should walk in a natural way, e.g. not backwards.

This test can be arranged in any real shop or supermarket. If the latter is also not possible, the test can be conducted in an arbitrary room containing multiple shelves. The only requirement is that this room is not part of the arena and that the teams do not know the room beforehand.

The shop in which the test takes place will be defined by EC/TC/OC on site just like the locations of the shelves, the location of the supermarket checkout and the locations where

the test starts and ends.

For safety reasons, a second team member needs to follow the robot and its guide.

If a person from the audience interferes with the robot in a way that makes it impossible to solve the task, the team may repeat the test immediately. Otherwise, this test cannot be repeated as there will be only a single slot where it can be carried out.

5.3.4 Referee Instructions

The referees will be composed of EC and TC members. They select the shop/room in which the test takes place, make local arrangements and select the involved locations and objects. Again, the objects will be chosen (for each team) according to the list of manipulable objects.

5.3.5 Score Sheet

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

Action	**Score**
Guide Phase	
Reaching a *location* in the guide phase	*4 × 50*
Navigation Phase	
Reaching a *location* in the navigation/manipulation phase	*3 × 150*
Grasping the correct objects	
Successfully grasping a correct object from the shelf	*3 × 200*
Successfully grasping from at least 2 different heights	*150*
Delivering the correct objects	
Successfully delivering (and handing over) the correct object to the user	*3 × 150*
No Touching	
Successfully solving the complete test in time without *touching* anything.	*150*
Special penalties & bonuses	
Not attending (see sec. 3.7.1)	*-500*
Outstanding performance (see sec. 3.7.3)	*200*
Total score	*2200*

5.4 Cleaning the House (Demo Challenge)

This year's demo challenge is addressing a universal problem: Cleaning up the mess in an apartment. Since this is the Demo Challenge, we are interested in any sort of cleaning. Use your imagination and demonstrate cool applications.

5.4.1 Focus

The focus of this test is on human-robot interaction, ambient intelligence, manipulation, situation awareness, multiple behaviors, robot-robot interaction, unknown object recognition, using household applications

5.4.2 Task

Tasks include, but are not limited to:

- cleaning up a table
- cleaning the floor
- vacuum cleaning
- dish washing
- cleaning the bathroom
- cleaning the toilet
- putting books in the the bookcase
- making the bed
- use water and soap to clean a surface
- clean the (bed) room of laundry lying on the floor
- put laundry in a basket
- get the basket to the washing machine
- empty the basket in the washing machine
- put laundry directly in the washing machine
- read the manual of the washing machine
- read the instruction on the soap box
- close the washing machine door
- turn on the washing machine on the correct program
- open the washing machine door
- recognize the type of laundry (colored, wool ,white, black, etc)
- get the clothes out of the machine
- put/hang the clothes to dry
- get the clothes from the drying device
- iron the clothes

- fold the clothes and put it in the cupboard
- pick up the clothes, hand them to a person who washes them, hand them to the robot and put them in the cupboard

The more capabilities that are shown, the higher the scores are. It is also very important that the robot is not demonstrating separate capabilities, but that a story is being told. The tasks the robot is performing should make sense to the audience. A maximum bonus of 500 points, on top of the 1500 points, can be earned if two (or more) robots from two different teams demonstrate successful collaboration, thus successful robot-robot interaction. For this purpose it is allowed to have a maximum of 4 robots in the scenario, two from every team. This bonus of maximum 500 points is earned for both teams. In case of 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.

5.4.3 Remarks

There is no fixed start signal in this test.

5.4.4 Referee Instructions

The referees need to:

- Understand what it is that the teams will be demonstrating and ensure that the environment is set up properly so as to not obtain undue delays.
- Make certain that at any time there are no more than 6 people in the scenario in total (including TC, trustees etc).
- Make certain that there is a TC member for every robot that participates in the challenge who writes down the best achievements of the robot in order to compare them with each other for the scoring.

5.4.5 Score System

2000 points max. The TC can give partial scoring of 1500 points for factors such as complexity of the task, robot performing multiple tasks (correctly), appearance/usability/HRI of the robot, appearance, safety, robot-robot interaction and excellent performance. It is more important to do one thing very good than many things not so good. Of course most points are awarded to teams that do multiple tasks very good. Although at least one TC member is monitoring the robot, the entire TC votes for the score. An extra bonus of max. 500 points (so it can also be partially rewarded) can be earned if two robots from two teams successfully collaborate (robot-robot interaction).For the robot-robot interaction, the robot(s) from the second team can only play a minor role in the total demonstration. It must be made clear that the two demonstrations from the two teams are not similar, otherwise the points cannot be awarded. Examples of multi-team interaction could be:

- Robot A from team X hands over an object to robot B from team Y

- Robot A from team X talks/instructs robot B from team Y using verbal communication
- Robot A from team X and robot B from team Y clean a room together where one robot shows where rubbish is and the other picks it up
- Robot A from team X put the laundry in the laundromat and robot B from team Y gets it out of the machine.

Chapter 6

Finals

The competition ends with the *Finals* on the last day, where the five teams with the highest total score compete. The concept is the same as in the Open Challenge. Every team in the Finals can choose freely what to demonstrate. The performance is evaluated by a jury and the Executive Committee. The jury will consist of people from various background, not necessarily only from robotics.

The demonstration in the Finals does not have to be different from the one shown in the open challenge (if any). It does not have to be the same either.

A wireless microphone and a video projector are provided.

6.1 Changes to the Environment

For the Finals teams are allowed to make modifications to the environment as they like under the condition that they are reversible and the team leaves the arena in the *very same* condition they entered it (i.e. revert all modifications made). The changes and their reversion have to be made within the total time given.

6.2 General Procedure

Each team has a 15 minutes time slot, which is split into two parts:

1. Max. *10min* setup, presentation and demo.
2. Max. *5 min* questions.

Further,

1. The presentation can be held while setting up.
2. The demonstration takes 5 min or more, which means the setup and presentation part takes 5 min or less.

Here, setup means reconfiguring the arena and getting the robot ready. Presentation means talking without the robot doing anything. Demonstration means that the robot does something and optionally someone is making comments on what is happening.

6.3 Setup and Presentation

During the setting up of the robot the team has to give a presentation in English for the audience. It should be made clear to the audience and the jury what they are about to see. Please note that the focus should lie on the demonstration and not on the presentation. There is no fixed start signal in this test.

6.4 Performance

The performance takes a minimum of *five minutes* and should be commented in English by a team member. In short: Focus on the demonstration!

6.5 Score System

The score in the finals is made up of three equal parts.

1. One third of the points is given by the *previous performance* of a team, i.e., the sum of points scored in Stage I and Stage II.

2. One third of the points stems from an *evaluation by the Executive Committee* which serve as "league insider". This evaluation is done according to the following criteria:

   - Scientific contribution
   - Contribution to @Home
   - Relevance for @Home / Novelty of approaches
   - Presentation and performance in the finals.

3. One third of the points is awarded by an *external jury*.
   The evaluation criteria of the jury are based upon the desired abilities described in Section 2.10 and the list of criteria below. A maximum of ten points is given for each of these criteria by each jury member.

   - Originality and Presentation
     (story-telling is to be rewarded)
   - Usability / Human-robot interaction
   - Multi-modality / System integration
   - Difficulty and success of the performance
   - Relevance / Usefulness for daily life

6.5.1 Jury Questions

After the performance there is a *five minute* period where the jury can ask questions to the team representative. The questioning influences the ranking and will be held in English.

6.5.2 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

DC	Demo Challenge	17
OC	Open Challenge	39
OC	Organizing Committee	2
TC	Technical Committee	2
TDP	Team Description Paper	9

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