



RoboCup@Home

Rules & Regulations

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Daniele Nardi Jean-Daniel Dessimoz Peter Ford Dominey Luca Iocchi Paul E. Rybski Jesus Savage Stefan Schiffer Thomas Wisspeintner Tijn van der Zant Amin Yazdani

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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

1.2.1 What is RoboCup@Home

RoboCup@Home is a new RoboCup league that focuses on real-world applications and human-machine interaction with autonomous robots. The aim is to foster the development of useful robotic applications that can assist humans in everyday life.

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. The terms are three years as shown.

Members representing the @Home league 2006-2009:

- Thomas Wisspeintner (Fraunhofer IAIS, Germany), thomas.wisspeintner[at]iais.fraunhofer.de
- Tijn van der Zant (Rijksuniversiteit Groningen, Netherlands), tijn[at]ai.rug.nl

1.3.2 Technical Committee

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

Members of the RoboCup@Home league Technical Committee for 2008:

- Paul E. Rybski (Carnegie Mellon University, USA), prybski [at]cs.cmu.edu
- Stefan Schiffer (RWTH Aachen University, Germany), schiffer[at]cs.rwth-aachen.de
- Amin Yazdani (Sharif University of Technology, Iran), aspersica[at]gmail.com

1.3.3 Organizing Committee

The Organizing Committee (OC) is responsible for the organization of the next competition of each league. The OC consist of members listed below.

Members for the @Home league 2007:

- Luca Iocchi (Università di Roma "La Sapienza", Italy), Luca.Iocchi[at]dis.uniroma1.it
- Jean-Daniel Dessimoz (Haute Ecole d'Ingénierie et de Gestion du Canton de Vaud, Swiss),

Jean-Daniel.Dessimoz[at]heig-vd.ch

• Jesus Savage (National Autonomous University of Mexico (UNAM), Mexico), savage[at]servidor.unam.mx

1.4 Infrastructure

1.4.1 RoboCup@Home Mailinglist

The official mailinglist can be reached at

robocup-at-home[at]ais.fraunhofer.de

You can register to the email list at: http://lists2.ais.fraunhofer.de/mailman/listinfo/robocup-at-home

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 an daily life environment. In stage 1, an Open Challenge is held. The 10 best teams from stage 1 advance to stage 2 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.

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 word-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 3.3.2).

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 2008 competition.

3.1 Scenario

The RoboCup@Home competitions take place in a home-like scenario. It consists of rooms such as a living room and a kitchen. There will be a designated area (e.g. a second room) which can be used for preparation.

3.1.1 Walls & Doors & Floor

The model of the indoor scenario will be surrounded by walls. These walls will be built up using standardized 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 will not be used at the moment. The walls will be fixed and will not be modified during the competition. There will also be two doors integrated within the wall setup.

On 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.

3.1.2 Furniture

An example of the arena is given in the figure 3.1. Please note that the actual arena will most likely look different. The arena will be equipped with typical objects with 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



(a) A sketch of a possible arena



(b) RoboCup 2006 Bremen - living room

(c) RoboCup 2006 Bremen - kitchen area



(d) RoboCup German Open 2007 Hannover

(e) RoboCup 2007 Atlanta

Figure 3.1: Possible configurations of the arena. The actual setting is most likely different from the pictures above and the positions of objects will change during the competitions.

plastic bottles inside. There is also a door with a handle (not a knob) which represents the entrance to the living room.

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.

3.1.3 Objects

Certain tests involve interaction with objects. The TC will compile a set of roughly ten different objects. Whenever a test involves an object it is taken from this set. The TC makes the set of objects and their names available during the setup days.

3.1.4 Locations

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

3.2 Equipment

3.2.1 Maximum number of people

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. 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, 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 be interviewed by the host of the event.

3.2.2 Robots

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

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.

Size of Robots

Any robot that can operate in a regular indoor environment is allowed to participate. Height is limited to 2 meters, weight is limited to 150 kilograms. Also a robot has to fit through a regular doorway (180x70cm).

Safety

Every participating robot has to be operated safely, being not dangerous to people and the environment. Therefore all robots have to have a marked "emergency off" button with good accessibility (preferably placed on top).

Requirements

Every robot should have a speaker output plug. This will be used to connect the robot to the sound system so that the audience can hear and follow when the robot is talking.

3.2.3 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*. There is no restriction on the kind of external devices a team is allowed to bring into the arena, as long as they are not harmful to other people or robots. The devices have to be easily portable and removable within seconds after the test. It can be all kinds of "natural" objects like a book, a glass, etc. Logo's, banners etc. are not allowed as devices to bring into the arena.

The Technical Committee has the right to refuse a device being put in the arena. If you are uncertain about whether or not a specific external object is allowed contact the Technical Committee in advance.

Number of external devices

The number of allowed external devices for stage1 and stage2 is 3. For the open challenge and the finals, there is no limit in the number of external devices.

Computing devices

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

Microphones

External microphones (also headsets) are allowed for now. A long-term goal is to integrate the microphones on-board. Teams that already use on-board microphones are rewarded an extra score of 50 bonus points per successful test. (see Bonus)

3.2.4 Wireless Communication

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.

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.

3.3 Procedures before the competitions

3.3.1 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.

3.3.2 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
- \bullet 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.

3.3.3 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

3.3.4 Poster

Every team should also prepare a team poster which explains features and scientific achievements. This poster will be used in the evaluation of a team such as in the Open Challenge.

3.4 Procedures during the competition

3.4.1 Stage System

The competition 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. (Similar to phase 1 of a test from the 2006 and 2007 competition). The *Open Challenge* will be done in Stage I so everybody can and should prepare for it.

Stage II

Only the best 10 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 (5) teams from Stage II advance to the finals.

3.4.2 Number of Tests

In Stage I, apart from the Open Challenge, the maximum number of tests that a team can participate in is *four out of five*. To participate in the Open Challenge the team has to participate in at least one other test in Stage I. Participation in the Open Challenge is not necessary to advance to Stage II.

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

3.4.3 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 3.4.9) are awarded for the robot's

performance only within the given time period.

Stage I

 $\overset{\circ}{O}$ The time limit for each test in Stage I is 5 minutes unless stated otherwise in the test description.

Stage II

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

3.4.4 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. Note, that the already achieved partial score for a test is lost in case of a restart and starts again with 0 points.

3.4.5 Schedule

The tests will be held in test slots of approximately two hours. A schedule for all teams is provided by the TC 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.

3.4.6 Referees

Two team members from two different teams – not from the team which is currently performing – are the *referees* for each test. In case of a different opinion the TC decides. Not showing up for refereeing will be remembered and can be a reason for not accepting the preregistration the next year. In case of equal or a very close amount of points the team that did not show up gets the disadvantage. The team may also get disqualified for to the Finals.

3.4.7 Robot start position

Unless stated otherwise the robot has to autonomously enter the arena from the outside through the open doorway. Remote control of the robot is forbidden, but e.g using a following behavior is allowed. Successfully entering by opening the closed door adds a one-time bonus of 500 points (cf. Section 3.4.9).

3.4.8 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.

3.4.9 Score system

The total score of Stage I including the Open Challenge determines the 10 teams that advance into Stage II. Then, the 5 teams with the highest total score (the sum of Stage I and Stage II) 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. In Stage I (excluding the Open Challenge), the maximum total score per test is 1000 points. In Stage II and the Open Challenge, the maximum total score per test is 2000 points.

Bonus

To foster research and development on some specific capabilities there are bonuses a team can try to achieve by demonstrating those capabilities.

- **Opening the door** An additional *one-time bonus* of 500 points is awarded for autonomously opening the closed door. To prevent open loop behavior, the referees reposition the robot slightly in front of the door. If the attempt to open the door is not successful, the team is allowed to proceed with the test without penalty within the rest of the time period. The door has a regular door handle, not a knob and will open to the inside.
- **On-board microphone** If an on-board microphone is successfully used in a test and if use of the microphone is required and makes sense a bonus of 50 points is awarded for each test. The minimum distance between the person speaking and the robot must be 50 cm.

3.4.10 Open Challenge

Within Stage I the Open Challenge (OC) is being held. 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.

3.4.11 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 5.5.

3.4.12 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.

3.5 Special Awards

3.5.1 Innovation Award

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To honor outstanding technical and scientific achievements 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 Introduce

The robot introduces itself and its team to the audience. The other team leaders evaluate the appearance and the presentation behavior of the robot.

4.1.1 Focus

The purpose of this test is for the teams to get to know each other. The focus is on speech synthesis, articulation, presentation and appearance.

4.1.2 Task

The robot enters the living room from one side. When it is at the designated spot in front of all the team leaders it introduces itself and the team to the other team leaders. A video projector can be used for presentation purpose. The operation of the presentation computer can be done by a team member. The presentation computer can be external. After the introduction, the robot leaves the living room through the other door. The total time for the introduction per team is *five minutes*.

4.1.3 Referee Instructions

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

4.1.4 Score System

Points ranging from 0 to 10 are given for the following criteria by each team leader:

Appearance The professional and appealing appearance of the robot is evaluated.

Presentation How advanced are the presentation skills of the robot, for example speech synthesis, gestures, facial expression?

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Movement How well does the robot move in the environment? Is it a smooth and robust movement?

The points given by each team leader are multiplied by 33 to receive a maximum of 1000 points per team leader. The total score for each team is then calculated by

 $\frac{\sum \text{team-leader-score}}{\text{number-of-teams}-1}$

4.2 Fast Follow

The robot has to follow a person while there are more moving objects in the environment.

4.2.1 Focus

The focus is on human recognition, tracking and safe navigation.

4.2.2 Task

The teams can freely select a person for the robot to follow (e.g. a team member). The two teams start simultaneously at the opposite entries of the arena. They have to follow the same path but in opposite directions. This means that they will have to pass each other. The total time for this is *five minutes*.

4.2.3 Referee Instructions

The referees need to

- specify and announce the path and the checkpoint to the teams.
- take special care of not interfering with the robots.
- check whether a team receives the passing score.
- determine which robot finishes the test first.
- detect whether a robot touches something.

4.2.4 Score System

Points are given for the following:

- **Checkpoint** 200 points are awarded for passing a checkpoint which lies after one third of the track.
- **Passing the opponent** 200 points are awarded for passing the opponent robot. To receive this the leader is *not* allowed to stop walking while passing the opponent leader and robot.
- **Completing the track** 200 points are awarded for having completed the track by leaving the room.
- **Fastest team** 300 points are awarded for having completed the track and being the fastest of the two robots.
- No touching 100 points are awarded for having completed the track and not having touched any object. Note that major collisions will result in disqualification for this test.

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4.3 Fetch & Carry

The robot has to retrieve a certain object.

4.3.1 Focus

The focus is on human-robot interaction, navigation, object detection/recognition, and manipulation.

4.3.2 Task

One object is chosen by the team from a the set provided by the TC. The referees place the object into a certain region in the scenario which is physically accessible to the robot's manipulator and not be visible from the robot's starting position.

The robot and a team member enter the arena together and got to the starting position near the entrance. The team member tells the robot to search the object, and is allowed to give one hint (e.g. "The teddy is near the TV") on the position. The robot searches for the object, grabs it, and brings it back to within one meter of the robot's starting position.

The object must then be easily removed from the robot by the person (this must be physically demonstrated) in order to get full credit for bringing the object back.

4.3.3 Referee Instructions

The referees need to

- Have the set of objects prepared ahead of time
- Have the locations pre-selected for which each object could be placed. Note that the locations may be different for each robot based on its manipulation capabilities.

4.3.4 Score System

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- **Understanding** 150 points are awarded for understanding the person and moving to the designated region.
- **Finding the object** 150 points are awarded if the robot finds the object. This needs to be indicated by turning towards the object within a maximum distance of 50 cm.
- Manipulation 200 points are awarded for successfully lifting the object, i.e. keeping it lifted for at least *five seconds*. If the object does not need to be on a single fixed height to be manipulated (i.e. variability of at least 10cm), another 200 points are awarded.
- **Delivery** 200 points are awarded for bringing the object back to a place within one meter of the starting position and the person has to get the object from the robot.

 \mathring{O} Leaving 100 points for autonomously leaving the arena within the five minute time-limit

4.4 Who's who?

A robot should be able to autonomously recognize persons. 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.

4.4.1 Focus

Human detection/recognition, face detection/recognition, safe navigation, human-robot interaction

4.4.2 Task

Three people, one known to the robot (e.g. a team member) and two (random) unknown persons selected by the referees, position themselves within a four meter radius of the door according to the referees' instructions. All people are standing and do not move around. They also have to face the robot at all times.

- 1. The robot enters the arena through the doorway and starts looking around for people.
- 2. When the robot finds a person it has to announce this and introduces itself to the person. Then it has to indicate whether this person is known or unknown to the robot.
- 3. If it is unknown the person and the robot introduce themselves to each other. The robot's introduction must be obvious to both the human as well as the referees. If the robot requires the human to perform some specific actions, this must be explained by the robot to the human during the robot's introduction. Whatever information the human gives the robot can be used later to show that the robot can "recognize" the person. This introduction must not involve touching any part of the robot.
- 4. This process continues until all of the people have been found or the robot decides that it has found as many people as it can.
- 5. Finally, the robot *autonomously* returns to the entrance and the people leave the scenario one by one. The person has to stand in front of the robot and face the robot for *10 seconds*. The robot has to greet each of the persons as they exit and give the correct identification what was learned during step 3. Once again, this greeting must not involve the human touching the robot in any way.

If the robot incorrectly announces that it has found a person (such as introducing itself to a plant), then this counts against the score. If the robot chooses to give up prematurely (say after only finding 1 person correctly), then the robot suffers no additional penalties. The time limit is *seven minutes*.

4.4.3 Referee Instructions

The referees need to

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- select the people before the test starts.
- select the location for each person to stand before the test starts.
- select the order in which the people leave the environment after the introduction phase.

4.4.4 Score System

Finding humans (correctly found humans - incorrectly found humans) * 100 points.

- Known or unknown humans (correctly identified humans incorrectly identified humans) * 100 points
- **Identification when leaving** (correctly identified humans incorrectly identified humans) * 100 points
- Leaving Another 100 points are awarded if the robot leaves immediately after the last humans leaves

For each partial credit, there can be no negative score.

4.5 Competitive Lost & Found

Two robots (from different teams) compete in finding objects.

4.5.1 Focus

The focus of this test is on navigation, object detection and recognition.

4.5.2 Task

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Two teams are competing simultaneously. Three different objects from the set of objects are placed in the scenario. It's the same three objects for both teams. The objects can be on the floor but there is at least one object not on the floor. The robots have to find those three objects as fast as possible without touching anything. A robot has to clearly indicate that it has found (and possibly identified) an object by facing it within a one meter radius and performing an action that can be identified by the referees.

The TC picks and places the objects. The objects remain the same during this test for all teams, but the positions will vary.

There is a maximum of *five minutes* for this test.

4.5.3 Referee Instructions

The referees need to

- select three objects before the test starts.
- place the objects such that they are visible for both robots from some point in the environment.
- count the number of objects found and identified per team.
- determine which team finishes this test first.

4.5.4 Score System

Finding For every object found 100 points are awarded.

Identifying For every object correctly identified (e.g. speech/display) 100 points are awarded.

Speed The first team to find all 3 objects correctly is awarded another 300 points.

Leaving the arena Autonomously leaving the arena within the time limit adds another 100 points. Even if not all objects are found, the robot can still receive this partial credit.

4.6 Open Challenge

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

4.6.1 Focus

Demonstrate new useful abilities/applications, new scientific approaches and possible new tests.

4.6.2 Task

The Open Challenge consists of a presentation, 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 presentation *only three slides* are allowed. The focus should lie on the demonstration. When the team enters, it has *three minutes* for the setup. Then the team has maximum *seven minutes* for presentation and 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 presentation, 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 Score System

The score is determined by the other team leaders. For each evaluation criterion (see below) a maximum of 10 points is given per team leader.

The points given by each team leader are multiplied by a factor of $\frac{20}{7}$ to receive a maximum of 2000 points per team leader. The total score for each team is then calculated by

 $\frac{\sum \text{team-leader-score}}{\text{number-of-teams} - 1}$

Evaluation Criteria

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

- Presentation of the approach to the audience
- Social relevance / Usefulness for daily life of the demonstration
- Human-robot interaction in the demonstration
- Robot autonomy during the demonstration
- Difficulty and success of the demonstration
- Appeal / Could elements of the demonstration become a future @Home test?
- Scientific value of the approach/Jury Questions

Chapter 5

Tests in Stage II

5.1 PartyBot (Who is Who? Reloaded)

The robot has to identify humans and bring a drink to one of them.

5.1.1 Focus

The aim of this test is to evaluate a robots capability to detect humans and learn their identity for recognition at a later point in time.

It also contains the following aspects: human detection/recognition, face detection/recognition, human-robot interaction, fast calibration, navigation, manipulation

5.1.2 Task

Four persons chosen by the referees are dispersed through the scenario and position themselves in a natural manner such as sitting at the table, on the couch, \ldots Two persons will be sitting and two persons will be standing. The host, the referees and the team members need to stay outside the scenario if they are not one of the four persons.

- 1. After the robot enters the scenario it has to find as many people as possible, and should get to know them well enough to be able to identify them later on.
- 2. After the robot has found all persons or decides to stop searching for more it moves to the refrigerator. It waits there to receive orders from any of the identified persons.
- 3. One person that is known to the robot is chosen by the referees to order a drink. This person goes to the robot (at the fridge), orders a drink, and returns to her original position. The drink is either handed to the robot by a human or the robot grasps the drink by itself. If the robot grasps the drink autonomously, the team can set up a place near the fridge for the robot to do so.
- 4. The robot delivers the drink to the correct person (who has returned to the same spot as during the introduction period). The robot then has to give the drink and

act polite.

The duration of the test is *ten minutes*.

5.1.3 Referee Instructions

The referees need to

- select & collect the four persons involved before the tests starts.
- select one of the persons detected and introduced to to receive a drink.
- look out for false positives.

5.1.4 Score System

detecting humans For every person detected and introduced to 200 points are rewarded if the person is standing and 300 points are awarded if the person is sitting. Falsely detecting a human where there is none gives a penalty of 100 points.

navigating to the fridge For correctly navigating to the fridge 100 points are awarded. **grasping the drink** If the robot grasps the drink by itself 200 points are awarded.

delivering the drink For delivering the drink to the correct person 400 points are awarded.

handing the drink If the robot hands over the drink by itself, 100 points are awarded.

leaving autonomously If the robot autonomously leaves the arena in time 200 points are awarded.

A team cannot leave this test with a negative total score but instead receives zero points.

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5.2 Supermarket (Lost & Found Reloaded)

The robot has to get a particular object from the shelf.

5.2.1 Focus

Human-robot interaction, manipulation

5.2.2 Task

A random person selected by the referees is using natural interaction (gestures, speech) without prior knowledge on how to use the robot, to get the robot to deliver a maximum number of *four* (4) objects from one or more shelves. The robot is allowed to give instructions on how it can be operated.

The *four* objects are taken from the set of standard objects (cf. Section 3.1.3). The team can choose two of the objects itself, the other two objects are chosen by the referees (respecting the physical constraints of the robot). The objects are then put on one or more shelves by the referees.

A team has to announce whether the robot is able to get objects from different levels before the test starts.

5.2.3 Referee Instructions

The referees need to

- select the person to interact with the robot.
- check whether the robot is able to get objects from different levels.
- choose two objects and ask the team for the other two objects.
- distribute objects among shelves and levels.

5.2.4 Score System

Correctly understanding which object to get For every correctly understood object 50 points, i.e. by clearly indicating the object.

Note that if the robot goes through the entire list of objects and asks whether this object is correct is forbidden and no points will be awarded.

Recognition For every correctly found object: 100 points.

- **Grabbing** For every correct object retrieved from the shelf 75 points are awarded. If the object was lifted for at least *five seconds* another 75 points are awarded.
- **Delivery** For every object delivered to the person: 50 points. It is allowed to deliver multiple objects at once.
- **Different levels** For getting objects from different levels 200 points are awarded.

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Multi modal input For using gestures in a meaningful way besides speech to communicate with the robot: 400 points

5.3 Walk & Talk

Introduce the robot to a new home.

5.3.1 Focus

This test evaluates the ability of the robot to build a (topological) map of a previously unknown environment and instantaneously using this map for localization and navigation to taught in positions (SLaM).

Furthermore it contains the following aspects: speech recognition, human recognition, human tracking, following, navigation, localization, map building, object recognition, intuitive calibration, behavior integration

5.3.2 Task

A robot is guided through an unknown environment and has to memorize a set of objects/places (Guide phase). Then the robot has to navigate to these object/places in random order (Navigation phase) proving that it was able to memorize these places.

Before the test, the arena is being rearranged in such way that a pre-built map can not be used in a useful manner.

A list of standard objects/places (e.g. Plant, Couch, Television,...) is published during the setup days (cf. Section 3.1.4). The referees pick a set of *five* objects/places of this list.

Guide Phase

One team member has to guide the robot through the arena making the robot to memorize the places and their names. Note, that only natural interaction with the robot is allowed.

During the Guide Phase, the team member can decide how many of the 5 objects/places it wants to teach in (2 places/objects minimum) depending on the time left. Also the order of visited objects/places can be chosen freely. The robot has be within a 1m range from the object/place.

Then, the team member needs to announce that the Guide Phase is over and that they proceed with the Navigation Phase. After this announcement it is not allowed to go back to the Guide Phase.

Navigation Phase

During the Navigation Phase, the referees pick memorized object/places from the Guide phase in random order, preferably with a long distance in between them. The team member has to tell the robot to go to these objects/places. The robot needs to indicate that it has arrived at an object/place. The robot has be within a 1m range from the object/place.

5.3.3 Referee Instructions

5.3.4 Score System

Following 100 points per object/place reached in the Guide Phase

Mapping/Navigation 250 points for each object/place reached correctly in the Navigation Phase

Navigation 100 points for going back to the starting position

Autonomous leaving 150 points for autonomously leaving the arena in time

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5.4 Cleaning up

The robot should clean up the arena from unknown objects.

5.4.1 Focus

The focus is on detection of unknown objects, navigation and interaction with objects.

5.4.2 Task

Within the environment there will be six different unknown objects, i.e. not from the set of objects mentioned in Section 3.1.3. The objects will have a minimum size of $10 \text{cm} \times 10 \text{cm} \times 10 \text{cm}$. They will be visually distinguishable from the floor and it is possible to move them around by pushing. That also means, that the objects will be placed in such a way that there is enough space around them for the robot to maneuver.

The robot's task is to detect the objects and to bring (e.g. push/pull/carry) them to a single designated area that the team or robot can choose on its own. The area needs to be same for all objects. It is not allowed to mark that area with a beacon. When the robot thinks it has encountered an object, it may test whether it has really found something by carefully trying to push it. The robot has to announce when it thinks it has actually found an object and start bringing the object to the designated area. All objects have to be within a circle with 1.5m diameter.

The total time for this test is *ten minutes*.

5.4.3 Referee Instructions

The referees need to

- distribute the objects before the test starts.
- count objects detected and collected.
- look out for false positives.

5.4.4 Score System

Detection 150 points for each of the six objects being detected following the procedure mentioned in the task description. The same object is not counted multiple times.

Pushing 150 points for every object successfully pushed to the designated area.No false positives 100 points for not falsely detecting an object where there is none.Leaving autonomously 100 points for leaving the arena autonomously.

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5.5 Robot Chef (Demo Challenge)

The robot assists a human in cooking.

5.5.1 Focus

human-robot interaction, ambient intelligence, manipulation

5.5.2 Task

The robot has to demonstrate the ability to assist a human while cooking in two different ways, one of which includes the physical manipulation of an object. This demonstration challenge is designed to give teams the ability to showcase their capabilities in a useful setting and application. This demonstration test is meant to give an idea as to what kinds of tests could be done in the future once the capabilities of the robots and technologies make it possible.

As stated before, the robot must succinctly demonstrate at least two different ways that it can assist a human in cooking. Cooking is typically a multi-step process that involves planning the meal, selection of ingredients, preparation of the cooking area, mixing of the ingredients, the process of actually cooking the food, and finally assembling the food on a plate (or plates) for proper presentation. Teams should select from at least two of the above steps (or create your own step) with the only specific criteria being that the two tests must demonstrate very different capabilities of the robot.

Examples might include (but are in no way limited to):

- Understanding what to cook, getting the recipe from the Internet and handing over some ingredient(s). This would typically involve having a conversation with the human whereby the human is asked what kind of meal that they would like to prepare (e.g. fish, meat, or vegetarian), and then the robot makes one or more suggestions that the human could choose. From there, the robot would help the human by identifying and locating the ingredients necessary for the meal.
- The robot helps the process of mixing the ingredients by being told to go and find at least two different tools, such as a spoon and a spatula, from the set of tools provided in the kitchen and then bring them to the human. The robot must be able to physically grasp and carry the spoons without assistance.

Please note that the specifics of what will be done should be made clear at the very start of the test to ensure that they will be considered sufficiently interesting by the referees to warrant full score if the robot is successful.

5.5.3 Referee Instructions

The referees need to

- Set up the kitchen area with the necessary props (books, simulated food items, and utensils) so that the robot is able to see and grab what it needs based on its physical capabilities.
- 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.

5.5.4 Score System

1000 points if the robot succeeds. 500 extra bonus points for the team(s) that perform extraordinary, decided on by the TC.

5.5 Robot Chef (Demo Challenge)

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 that 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 Setup and presentation

During the setting up of the robot (max. 10 minutes) the team has to give a maximum five (5) minutes 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.

6.3 Performance

The performance takes a maximum of *five minutes* and should be commented in English by a team member.

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6.4 Evaluation criteria

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.

- Scientific contribution / Contribution to the community
- Relevance / Usefulness for daily life
- Usability / Human-robot interaction and multi-modality
- Originality and presentation of the performance
- Difficulty and success of the performance
- Previous performance (\mathcal{P}_p) computed by

$$\mathcal{P}_p = \operatorname{round} \left(\frac{\operatorname{Total team score from Stage I and Stage II}}{\operatorname{Total score of best team from Stage I and Stage II} * 10 \right)$$

The total score is the sum of the scores from each of the different categories. The maximum score determines the winner.

6.5 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.

6.6 Winner

The winner of the competition is the team that gets the highest ranking in the finals. Thus, the ranking is independent of previous results except for the 'Previous Performance'criterion.

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.

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OC	Organizing Committee	2
TC	Technical Committee	2
TDP	Team Description Paper	14

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