RoboCup: Yesterday, Today, and Tomorrow Workshop of the Executive Committee in Blaubeuren, October 2003

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1 Introduction (by Manuela Veloso)

RoboCup has been known for the goal of "creating robots capable of beating the world cup in 2050." Clearly, we stated this goal back in 1996 not as an exact scientific goal, but as an audacious challenge to pursue. We aimed at creating a far away target for RoboCup researchers, as we were well aware that the development of fully autonomous soccer robots capable of competing against human world champion soccer players was a rather long term research project.

Although this goal exists, the real RoboCup characteristic has been the research pursuit of its participants to advance the scientific state of the art of the

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fields of artificial intelligence and Robotics. And from its beginning, we have organized RoboCup along a set of different leagues that provide different research challenges for multi-robot systems in complex environments. Initially, we created robot soccer leagues. In our research pursuit within robot soccer, we soon realized that our techniques could be applicable to other complex environments, such as search and rescue. Furthermore, we understood that our long term goals required the education of children in robotics. So we started Junior leagues for young children.

The RoboCup competitions include now three major areas, namely RoboCup soccer, RoboCup Rescue, and RoboCup Junior. We present and discuss research contributions in the RoboCup Symposium. Furthermore to better share research interests among different leagues, we created RoboCup Camps for students and Special Interest Groups (SIGs).

In 2003, and about six years after the first official RoboCup competitions at IJCAI'97 in Nagoya, we had a special two-day meeting of the Executive Committee in October 2003. We specifically discussed the immediate directions and roadmap for each league towards our 2050 goal. This article summarizes the results of this meeting. The article is organized along the different leagues, research, and education.

2 **RoboCup Roadmap** (by Hans-Dieter Burkhard)

The workshop (Oct. 4th- 5th, 2003) can be understood as a continuation of the panel discussions in Fukuoka 2002 and Padova 2003. The 2050 goal, to win with a team of fully humanoid robots against the human world champion serves as the long-term vision. It sets up high challenges, which need to be solved step by step, and in corporation with other sciences. We are not done with a perfect kicker for let's say Midsize League - instead we will change the conditions of our leagues and our players year by year, according to ambitious scientific problems.

A questionnaire was sent to the participants before the workshop. The questions concerned the problems to be solved until 2050, the meaning about RoboCup benefits, and the development of our championships and conferences. Here are some results concerning the necessary steps in RoboCup:

- Perception appears as the mainly mentioned and discussed challenge in the questionnaire: Recent shortcomings and future requirements (outdoor field, unpredictable lighting) are next steps to be solved. Expectations range from 10 - 20 years for their solutions.
- Robust (humanoid) hardware that can move on outdoor grounds and can handle the ball like humans do - this will still last 15, 20 or even 30 years.
- Safe interaction with humans is one of the most important problems, again it will require a long time. It is an open questions which restrictions are necessary for fairness (e.g. are robots allowed to use wireless communication - or the other way round: will humans be allowed to use additional technical equipment?).

- Adaptation and learning to play as an individual and as a team against an opponent with unknown (but partially observable) intentions and skills: 10-20 years were expected for really useful solutions.
- Body control will become a hard problem as soon as we are able to build humanoids which can run, jump etc.: We will have to control a large number of parameters under complex dynamics.

The answers in this category of the questionaire were mainly focussed on Robotics from an AI and Informatics centered viewpoint - like perception, learning, cooperation. Topics like new materials and energy are subsumed under the general hardware problems, but are not considered in detail. To play a major role, RoboCup will have to enlarge efforts in these directions. It will need cooperation with other sciences.

Another category was called "Benefits of RoboCup". It was the aim to collect answers which are useful for discussions and for funding. Many answers were related to the solutions of the problems from above. The benefits for education and studies in Robotics were pointed out. RoboCup Junior has an important role for promotion of RoboCup. RoboCup Rescue is a convincing application, and it needs further solutions behind the scope of soccer playing robots.

Commercial applications may concern service robotics and robust solutions for many other problems. It was discussed, how far scientific institutions can and should invest their power in the development of industrial applications. The conditions (and needs) are different in different parts of the world. In any case, it would be good for the image of RoboCup to know about applications with origins in RoboCup. Again, the cooperation with other scientists is necessary to prevent from "reinventing the wheel" - and to promote our results.

A next category was related to the development of RoboCup Championships and Conferences. There was a remarkable tendency for concentration: Not more leagues, but merging of existing ones. The cooperation between the leagues should increase (e.g. by comparable challenges, exchange of solutions etc.). The Symposium could be devoted to special topics of common interest, and people from the related communities should be invited. Most important: RoboCup should become a first-rate, prestigious conference.

During the Workshop, each league gave a report about their development and their plans. These reports together with the related further discussions are part of this article (see below). Additional reports were given about the SIGs.

RoboCup has become a good visibility and reputation in many other communities, and RoboCup is often used for examples and illustration. Our progress is observed from outside, especially for educational efforts in AI and Robotics. Most of the reported comments are positive, but still we have to promote our scientific goals. The best way are presentations of our results at various conferences and journals. The participation of RoboCup researchers in other robotic research projects is another important way.

Besides the more technical viewpoints, the Robotics projects are important for the Human Sciences, too. Soccer is a good scenario to study natural (hu-

man) skills, the Robotics perspective opens new insights. More about CDR - the Cognitive Development Robotics - can be found in M. Asada's section below.

As our leagues are pursuing new challenges, it becomes harder for beginners to start in RoboCup. Especially for education, where RoboCup scenarios are used to develop the skills of students in a restricted time, a simple setting is necessary. An "Entry"/"Educational"/"Easy" League (ELeague or Uleague="Undergraduate" League, cf. the section of B.Sklar on the Junior League below), may be on the level of recent Small Size League, could be useful for such purposes. A concrete proposal will be developed.

Small Size League in its recent format seems to be at a final point: New challenges for this league point to the direction of Midsize League. Cooperation in Midsize League is an important future milestone. It can be best realized with more players on the field. The conclusion of these discussions is the merging of Small Size League and Midsize League to one League in the next years until 2006. Concrete proposals are to be discussed between the leagues.

As a next step for better perceptional skills, all real robot leagues will reduce the efforts for special lightings and special field designs step by step in the next years. It is the hope, that there will be an exchange of e.g. successful vision systems between the leagues. Common challenges should be defined by the SIGs.

There were several more important topics discussed in Blaubeuren, e.g. the design and maintenance of a common webpage for tutorials, exchange of useful solutions, discussions etc. It works fine on the level of the leagues, but it would be good to have a common page. Like the pages of the leagues, the project should be realized by volunteering.

3 RoboCup: Yesterday, Today, and Tomorrow – Humanoid Science Approach – (by Minoru Asada)

Abstract. The sectionr presents the summary of talk in the RoboCup Workshop at Blaubeuren, Germany, Oct. 4-5th after the RoboCup-2003 Symposium. The talk starts from the early beginning of RoboCup and raised the future issues towards the final goal, that is, roadmap discussion and its related issue. Finally, new activities for RoboCity CoRE was introduced.

3.1 Introduction

The very early days of RoboCup starting from 1993 to 1995 was introduced and the story about the rejection of the authors' first RoboCup conference paper in 1994, which as a result activated the promotions of RoboCup in small workshops is mentioned as RoboCup yesterday. The RoboCup today was just shown as the number of participating teams at RoboCup 2003, Padova.

Review of future issues in RoboCup from different viewpoints are given. They are research, education, industrialization, and connection to the general society. The rest of the section gives the summary of these activities and issues.

3.2 Research: A Humanoid Science Approach

Two aspects of the research issue are pointed out: funding strategy (how naming "RoboCup" explicitly does help us?), and research topic (what's our unique but not too specific topic?). For the former, data of the past and on-going projects funded from governments, public organizations, and industries will be collected for future funding based on RoboCup. For the latter, a humanoid science approach is proposed as one of the scientific topics towards the final goal.

"Humanoid Science" under which a variety of researchers from robotics, AI, brain science, cognitive science, psychology and so on are seeking for new understanding of ourselves by constructivist approaches, that is expected to produce many applications. The humanoid science turns the research topics in RobopCup as follows:

- mechanical design for individual robots → design of humanoid platforms,
- robust sensing, especially, vision (object discrimination and tracking) → attention mechanism,
- self-localization and map building → body representation (body scheme or body image) and spatial perception,
- control architecture → freezing and releasing DOFS, NLPCA, SOM,
- communication → symbol generation and language emergence,
- multiagent systems in general → social interactions,
- combining reactive and modelling approaches → embedded structure (nature) and interaction with environment (nurture),
- sensor fusion → cross modal association for body representation (body scheme or body image), and
- cognitive modelling in general → theory of mind.

Cognitive Development Robotics (hereafter, CDR) as one approach to humanoid science [1] consists of the design of self-developing structures inside the robot's brain, and the environmental design: how to set up the environment so that the robots embedded therein can gradually adapt themselves to more complex tasks in more dynamic situations.

Brief explanations on developmental learning for Joint attention [2], and vowel imitation [3] are given as typical examples of CDR.

3.3 Design of Humanoid Platforms

The current participating teams are using commercially available or provided platforms such as Honda Firstep and Fujitsu HOAP focusing on behavior generation based on these platforms, or completely home-designed humanoids focusing on the design theory and implementation (mechanical structure, sensor, actuator, controller, and so on). Definitely, the latter is very challenging and very hard. Therefore, collaboration with industry is indispensable.

A small company (Vstone) developed a small humanoid platform: omni head that originally designed for Robo-One with a reasonable price. The height and the weight are 290mm and 1.9kg, the number of DOFs is 22. This sort of cheap

platforms is not simply useful for research but also for education as a kit product for high school or college students who are currently not involved in RoboCup activities.

Collaboration with industry including ventures seems necessary for the development of standard parts such as sensors, actuators, controllers, and so on. One can make competition like AIBO league, say, Qrio (SDR-4XII) league or Vstone league will be possible. Robot Technologies (hereafter, RT) incubation center is needed for joint development of robot standard parts and new RT products since RT is an amalgam of various kinds of artifacts.

3.4 RoboCity CoRE: An Inner City RT Base

A basic concept of RoboCup are an international joint research, a landmark project: sharing the dream, and open to different disciplines, open to public. Currently, the competition and conference is once a year, and a natural extension of RoboCup concept is to have a permanent place to deploy our activities.

RoboCity CoRE (Center of RT Experiments) is an inner city labs for symbiotic experiments with robots, new partners of our future life. CoRE aims at only one RT base around the world where simultaneous progresses of research, industrialization, and education carry on simultaneously.

Open to public means that researchers, artists, companies, citizens interchange with each other to emerge new ideas, that leads the development of science, technology, and culture. CoRE will be a new cultural symbol of the future high-technological, ecological city.

(a) (b)

Fig. 1. A humanoid platform:Omnihead (left) and open filed in RoboCity CoRE (right)

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4 **RoboCupJunior** (by Elizabeth Sklar)

RoboCupJunior (RCJ) has been growing and changing since its inception, this year reaching 75 teams from 16 countries for a total of 258 participants (see figure 2 for details). In 2003, there were five challenges: 1x1 Soccer, 2x2 Soccer, Rescue, Dance, and ULeague. The overall participation rate of female students was 15%, while within the Dance category, this was concentrated at 31%. As the league continues to mature, its internal structure and its role within RoboCup must adapt.

	2000	2001	2002	2003
number of teams	25	25	65	75
number of countries	3	4	12	16
number of participants	100	118	236	258

Fig. 2. RoboCupJunior participation, 2000-2003

4.1 Organizational Issues

The organizational action items for RoboCupJunior from 2002 were:

- to define a role for undergraduates;
- to continue to close the "gender gap" (i.e., increase participation of female students); and
- to establish national committees in participating countries.

These have been partially achieved. The proposed role for undergraduates is a new challenge, dubbed the ULeague. This is discussed at length below (see section 4.3). The gender gap is still too great, but particularly due to the Dance challenge, RoboCupJunior is succeeding in attracting and sustaining participation by female students. National committees have been established in several countries. Those most active are Australia, Japan and Germany. National representatives from several countries were chosen in 2003 to serve for 2004.

Two new organizational action items came up in 2003. The first is in regard to age groups and the second concerns record-keeping. Initially, the plan for RoboCupJunior was to provide an introduction to RoboCup for young students — primary through high school age. In 2000, there were three age groups: primary, up to age 12; middle, ages 12–15; and secondary; ages 15–18. For 2001

and 2002, there were two age groups: primary, up to age 12; and secondary, ages 12–18. For 2003, an experimental challenge targeted at the undergraduate age group was created (aka, the ULeague); thus there were three age categories: primary, up to age 12; secondary, ages 12–18; tertiary, ages 18-22.

For 2004, the RoboCupJunior Technical Committee has made the decision to raise the boundary between primary and secondary age groups from 12 to 14 years of age. The reason for this is that at international events, there is very little participation in children below age 12. This is primarily because international travel is expensive and complicated for young children due to issues of language and chaperones. However, at these international events, two groups of students have emerged: one group centering around age 13 and another group centering around age 16–17. Thus for 2004, the age groupings will be divided into three categories: primary, up to age 14; secondary, ages 14–18; tertiary, ages 18-22. Note that individual countries, on the national level, may choose to re-align these boundaries, as is appropriate for their regional events. However, it must be emphasized to participants that the international rules will follow these boundaries and so students must be prepared, at the international level, to adhere to this structure.

The second new issue that arose in 2003 is that record-keeping has become quite difficult. Most of the time, there is very poor correlation between those students registered by a team at pre-registration time and those students who actually come to the event. As a result, it is extremely difficult to provide accurate statistics, and it is very important, particularly for Junior, to be able to produce these figures to the media and potential funders. It is suggested that for 2004, on an international level, registration of all team members be centralized in one database. This registration would pertain not only to students who attend the RoboCupJunior events, but also to all students who participate at home in preparing for RCJ events.

For 2004, the organizational goals include: (1) defining a better structure within the RCJ organization; (2) recognizing and responding to needs of the RCJ audience and participants, who are quite different from their counterparts in the senior RoboCup leagues; (3) developing an on-line forum for teams; and (4) creating a funding mechanism especially for RCJ. The League Chairs for 2004 are Elizabeth Sklar and Jeffrey Johnson. The Organizing Committee Chair for 2004 is Gerhard Kraetzschmar. The Local RoboCupJunior League Chair for 2004 in Lisbon is Carlos Carderia.

4.2 Technical Issues

The primary technical action item for RoboCupJunior from 2002 was to develop stepping stones from RCJ into the senior RoboCup leagues. The ULeague was created in answer to this call and is discussed in detail below in section 4.3.

The RoboCupJunior Rescue event was resurrected and re-designed. In 2000, there was a line-following Sumo challenge, which provided an intermediate-level

task for middle-school age students. The environment is (fundamentally) static[1], however in order to perform line-following accurately, robots must be designed and programmed with skill and precision. In 2001, this event was modified as a RESCUE challenge, following the introduction of the RoboCup Rescue League at the senior level. The original intention for RCJ was that each host country would define a simulated disaster environment relevant to their local region, but always keeping within the structure of a static, line-following event. However, in 2002, this event was dropped, a controversial decision made by the local organizers. In 2003, the RoboCupJunior RESCUE event was re-designed, as a miniature version of the NIST Rescue Arenas used at the senior level. The RCJ RESCUE looks almost like a doll's house and the robots have to follow a line through the house, in and out of rooms, up and down ramps, searching for and identifying "victims". This event was well-accepted and there were numerous participants from several countries. For next year, some standards need to be published for construction and scoring, but overall, the challenge is a success and will undergo much change.

For 2004, other goals include (1) creating an outreach program/incentive for graduate and undergraduate students to mentor RCJ teams; (2) beginning discussion of a RoboCup exchange program; and (3) developing a book on *Educational Robotics through RoboCup*. The use of undergraduate students as mentors for Junior teams has been particularly successful in 2003. One hope for the near future is to create a formal mentoring program in which senior-league student team-members who also participate as mentors for Junior teams receive reduced (or free!) registration fees for the RoboCup event. Another proposal for the near future is to establish a formal exchange program for graduate students from RoboCup labs to visit other RoboCup labs around the world. This is already happening informally, but if a more formal program were established, it might open up the door to further technical exchange, understanding and advancement. Finally, a resource textbook is being developed, focusing on *educational robotics* through RoboCup. The idea is to create a resource for instructors teaching undergraduate courses on topics such as Artificial Intelligence, Programming, Autonomous Agents and Multi Agent Systems, using RoboCup as an example for demonstrating technical topics. The book will be a compilation of experiences, curricula and resources contributed by RoboCup team leaders and participants who have taught these courses. RoboCup and RoboCupJunior are together uniquely posed to be leaders in educational robotics on an international basis; such a book will help achieve this goal.

4.3 Discussion

The most contentious issue which has been raised within RoboCupJunior is the place for undergraduates within RoboCup. Currently, there exist students who have "graduated" from RoboCupJunior and are now embarking on their

[1] In SUMO, both robots perform at the same time on the same field, so technically the environment is dynamic however not on the same scale as on the Soccer field.

undergraduate education. However, there is no obvious place for them within RoboCup, especially if they do not attend a university where there is already an active RoboCup team. This motivated the formation of the experimental league within RoboCupJunior which has been mentioned above — the ULeague. This league takes the existing RoboCupJunior 2x2 soccer game and combines it with the Small-Size League (F180), simplifying issues of vision and communication. It was demonstrated successfully in Padova 2003 with teams from four countries (USA, Canada, Australia and Germany) and is reported in [1].

This ULeague was a topic of much discussion at the Blaubeuren meeting. There was some concern that the name is a misnomer. Many, many senior league RoboCup teams are composed partly, even primarily, of undergraduate students. So calling this new challenge the ULeague and emphasizing that it is for undergraduates is perhaps not consistent with existing practices. There was discussion about merging the existing Small-Size League (Smallsize League) with the ULeague, as it appears that there will be many changes to the Small-Size League setup over the next year or two. Out of the 24 teams that compete in Smallsize League, there are apparently only 8 who consistently perform well, year after year. For these teams, it is appropriate to move to a larger field, begin to move to local vision, to remove special lighting and to add more robots to the field. But the other 16 teams are not ready to meet these challenges.

This opens up the question of the role of RoboCup and RoboCupJunior. If the purpose of RoboCup is to advance the state-of-the-art in Artificial Intelligence and Robotics research, then it is not in the interest of the initiative to hold back advances and "wait" for the masses. On the other hand, if the leagues progress too fast, then they will only be accessible to the elite. If the purpose of RoboCup is to bring together researchers from different fields to work together to achieve a common goal, then it is not in the interest of the initiative to push advances beyond the reach of the "masses".

The goal of RoboCupJunior has been to introduce the RoboCup initiative to young students. As well, once RCJ has succeeded in engaging students, somewhere in RoboCup, there must be a mechanism to keep them engaged, as they grow up beyond high school to undergraduate to graduate school. As the gap between "entry-level" and competitive level in each league widens, somewhere within RoboCup, there must always be a bridge from an entry-level to wherever the senior leagues are.

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5 **Education** (by Daniele Nardi)

RoboCup devotes a special effort to Education, not only through the Junior League, but also by organizing specific initiatives, that are targeted to students

at University level. The aim of these activities is to support the creation and strengthening of the technical and scientific background and skills, that a student needs to successfully participate in RoboCup.

The design and implementation of a team of autonomous soccer players or rescue agents, certainly relies on basic knowledge and skills that can be acquired during University undergraduate and graduate curricula in several branches of Engineering (e.g. Computer, System, Telecommunication, Electronic, Electric, Mechanical). However, in order to realize RoboCup teams (or better, contribute to the realization of RoboCup teams) technical knowledge on specialized issues, that are often not covered by the University curricula, is required. In addition, RoboCup provides a unique challenge to implement complex systems requiring knowledge on a wide set of disciplines and a large spectrum of technical capabilities. Finally, from an educational standpoint, the RoboCup framework is instrumental to train the students to a scientific development of ideas, which requires the ability to understand the technical knowledge available in the literature and use it as a basis for the development of original and more performant artefacts. The Education effort within RoboCup addresses all of the above aspects.

The main educational activity organized by RoboCup is the RoboCup CAMP. RoboCup CAMPs are directed to newcomers to help them entering RoboCup competitions both from a methodological and from a practical point of view; moreover, RoboCup CAMPs are also addressed to practitioners that need to address some of the technical challenges in a more systematic and solid fashion. The name "RoboCup CAMP" wants to convey the idea that a CAMP is not only a highly specialized school, but it requires the active participation of the students. The goal of RoboCup CAMPs is very ambitious, because the aim is to introduce some background knowledge on specific techniques that are used in the realization of a soccer/rescue team, while trying to fill all the steps to the actual implementation. Usually, the RoboCup CAMPs are targeted to specific leagues, and consequently focus on issues that are more relevant in that context. In addition, at the RoboCup CAMP the students are shown how novel ideas needed to improve on the state of the art techniques for specific problems can be effectively developed. Finally, the RoboCup CAMPs are used as opportunities for successful teams to present in a coherent and systematic way the techniques developed, far from the pressure of the competition.

The RoboCup CAMPs held so far are listed below (more information about them and access to the documentation can be found through the RoboCup web site):

- Padova (Italy), February 2000 - Mid size
- Paris (France), April 2001, Small and 4-Legged
- Paderborn (Germany), April 2002, Mid size
- Bremen (Germany), August 2003, Humanoid and Small size

RoboCup CAMPs in Japanese have also been held in conjunction with the Japan Open.

Another issue concerning RoboCup Education effort that deserves consideration is the use of RoboCup frameworks as a support to the teaching activity

in several University courses, Summer Schools and tutorials. There are several examples of courses on Multi Agent Systems, that use the RoboCup soccer simulator as a testbed, as well as courses on robot constructions that focus on the robots of the small-size league. For example, the EURON Summer School on Cooperative Robotics (Lisbon 2002) had significant contributions using RoboCup as scenario. The references are available in the league web pages.

Finally, as a follow-up of the teaching based on RoboCup frameworks, textbooks collecting teaching material as well as teaching experiences based on RoboCup are forthcoming.

6 **Rescue League** (by Adam Jacoff)

The second annual RoboCup - Rescue Robot League competition, which took place in Padova, Italy, showed the gaining strength of our league. Twelve teams participated in a vigorous competition, a 50% increase in teams from the previous year, and we continue to raise awareness of the opportunities for robots in urban search and rescue (USAR) applications. Thus, we expect to maintain an aggressive growth rate for the 2004 event, hosting 16-20 teams in Portugal. In addition, we are actively engaged in efforts to expand the Rescue Robot League into the RoboCup national open competitions throughout the world. This year marked the first such rescue competition at the Japanese open, using the arenas fabricated for last year's Fukuoka competition. And a new year-round arena, hosted by Carnegie Mellon University in the USA, was used for rescue robot demonstrations at the first such American open event. The Italian rescue arenas, fabricated this year in Padova, are being set up at the Instituto Superiori Anticendi in Rome, a fire-rescue training facility, and will be available for year-round robot practice starting this winter. They may even host an Italian rescue event in the near future, either an Italian open competition or maybe a RoboCup camp devoted to Rescue Robot League research issues. Also, we are actively trying to get rescue arenas fabricated in Germany to host a rescue competition at the next German open event, and be available for year-round practice for central European researchers. The current site being considered to host these arenas is the International University in Bremen. So the league is expanding quickly due in large part to the enthusiastic response from researchers looking to test their robot's capabilities in the unstructured world of USAR applications, and work on the cutting edge of human-robot interaction for the betterment of disaster response.

Several changes to the league rules were initiated this year. One change discourages parallel teleoperation, where robot/operator control strategies are replicated within teams simply to inflate scoring. This year, specific starting positions were identified and sequential negotiation of the arenas was enforced, although teams could advance as far as they wanted through all three arenas. The first mission of each round started in the yellow arena, allowing direct comparison of navigation and mapping capabilities across teams. In subsequent missions, the teams were allowed to start directly into more advanced arenas to allow purpose built robots to highlight their specific capabilities. Also, false victim identifications were discouraged for the first time, so teams that mistakenly identified

sensor signatures as signs of life suffered point reductions. These changes were generally appreciated by the teams, and produced a balanced competition that promoted the pertinent research issues while discouraging certain teaming strategies. Minor rules modifications proposed for next year may artificially limit the use of radio communications during missions to simulate radio signal dropout and interference that occurs at actual disaster sites. This would also encourage development of more autonomous behaviors and tether management systems, both very beneficial assets in eventual deployment systems. Also regarding radio communications, we may encourage a move toward the 5 GHz frequency range and 802.11a communications protocol to generally improve communications bandwidth and performance in the complex environments of our rescue arenas and avoid conflicts with other leagues at these large competitions (which only hints at the radio spectrum difficulties of a real disaster site).

Also this year, we began systematically capturing each team's human-robot interfaces (HRI) for subsequent analysis. Researchers from the National Institute of Standards and Technology (NIST) performed the data capture which included interviews with the operators, a workload assessment, and continuous video capture of robot performance. These interfaces will be analyzed for effective elements or combinations of elements and overall statistics will be published. This HRI analysis effort will be augmented next year with automatic position tracking of the robots throughout the arenas via a new ultra-wideband tracking system, also provided by NIST. Objective robot tracking data such as this, along with operator interface and workload analysis, will provide researchers with important measures of performance of their robots (and other robots), and help identify "best in class" algorithms, sensors, and mechanisms. Hopefully, this will further encourage collaboration around the most effective components and methods, and quicken the pace of technical advancement in the field.

As our league evolves, we are keenly aware of the urgent need for practical robotic solutions for disaster response. Toward this end, we have appointed the following Technical Committee members with distinguished, diverse backgrounds in robotics and disaster response to help steer our league: Dr. Andreas Birk (International University in Bremen, Germany), Dr. Ali Meghdari (Sharif University of Technology, Iran), Dr. Ted Sumrall (President, Counter Terror International, USA/Japan).

In recent times, it has become ever clearer that robots are needed to support first responders and rescue professionals at disaster sites. Many nations are supporting this endeavor, and Japan is among the leaders. Since their disastrous Hanshin-Awaji earthquake near Kobe (and others), they have aggressively supported research and development of robots for search and rescue applications. In 2002, the Japanese Ministry of Education, Culture, Sports, Science, and Technology (MEXT) started a five year project specifically focused on earthquake disaster mitigation in urban areas aimed at developing advanced robots and information systems for disaster response. The International Rescue System Institute, headed by our league chair Dr. Tadokoro, is one such example in that effort, supporting over forty research projects within Japan.

Efforts such as these will provide the funding required to push the technology and methods forward quickly. Evaluating the progress of these research efforts, and encouraging collaborations between organizations to better leverage advances, is where our league will play it's most important role. Our arenas represent standard, representative problems for the community at large. Our metric provides object evaluation of performance and encouragement toward clearly needed capabilities. And our competitions provide intensive, periodic development efforts and collaboration opportunities as teams react to the representative rescue situation at hand and attempt to follow increasingly realistic operational procedures adopted from at actual disaster sites. Practice sessions such as this, without risk to life or robot, can hardly be over valued. And it can play a pivotal role in increasing the rate of advancement in robotic capabilities.

As robot teams begin demonstrating repeated successes against the obstacles posed in the arenas, the level of difficulty will be increased accordingly so that the arenas continue to provide a stepping-stone from the laboratory to the real world. Meanwhile, the yearly competitions will provide direct comparison of robotic approaches, objective performance evaluation, and a public proving ground for field-able robotic systems that will ultimately be used to save lives.

7 From the Discussions Concerning Smallsize League, Midsize League and Humanoid League
(Using Materials from the Slides by Gerhardt Kraetzschmar, Thomas Christaller, and Changjiu Zhou)

Smallsize League discusses changes (individual vision, larger field etc.) which makes this league closer to Midsize League. Smallsize league in its recent form is needed for beginners (cf. B.Sklar's section on Junior League above), while scientific challenges could be better pursued using the rules and settings of Midsize League. Moreover, Midsize robots will be smaller in the future. Planned and/or discussed changes in Midsize League concern:

- Less well-defined lighting.
  No special lighting (maybe even limited natural light influence) in 3-5 years.
- New ways of ball manipulation.
- Increasing players-pre-field ratio (larger fields and smaller robots).
- Game instrumentation: referee box, tools for recording and evaluating game data. The referee box is intended to become a common tool for all leagues.
  Almost no human interference in 3-5 years.
- Behavioral constraints instead of size rules and shape restrictions.
- Activation of many FIFA rules (corner kicks, throw-ins, goal kicks, free kicks).

As a consequence of the discussions in both leagues, Midsize League and Smallsize League will merge in the next years.

Humanoid League will use Midsize League field in 2004 and perform new challenges (e.g. more complex walking, more complex kicks, passing for soccer and

balancing for "Free Style"). True dynamic walk, run and jump are considered for the near future. They may lead to new technical solutions like artificial muscles, flexible joints, endo-sceleton construction The following roadmap is proposed:

2004: Balancing challenge, passing challenge, obstacle walk challenge.
2005: Match 1 vs 1, object following, multiple objects tracking.
2007: Match 2 vs 2, collision avoidance, safety issues.
2010: Cognitive issues, coordination of perception and locomotion.

A lot of different robots of humanoid type are expected for the future. Nevertheless, there should be a limited number of different competitions. One might think of

- Small-size Humanoid League (SHL) with global vision and focus on walking and kicking issues.
- Mid-size Humanoid League (MHL) with local vision and focus on integration.
- Humanoid simulation (cf. M.Riedmillers section on Simulation League below).

A lot of problems are common to all leagues, and many of them are already covered by the SIGs (the below). Common challenges are considered as useful means for common work.

8 Future Directions for the Four-Legged League (by Claude Sammut)

The distinguishing feature of the four-legged league has been that all teams use a common hardware platform, the Sony Aibo. Since the platform is fixed, the teams are freed from hardware design concerns and are able to concentrate on software development. The common platform also means that teams are easily able to share programs. These features have allowed the league to progress rapidly since new teams can quickly become competent by using previous code as examples for their own development and experienced teams are able to understand, in detail, how other competitors have solved similar problems. Code sharing is an essential part of the four-legged league and should remain so for the foreseeable future. Thus, it is important to continue using a common hardware platform and associated operating system.

As in all RoboCup leagues, the intention of the four-legged league is to progressively handle more natural environments and develop cooperation amongst teams of robots. This effort is leading to improved vision and localisation algorithms; a better understanding of information sharing between team members and faster and more stable legged locomotion. An important side effect of this research is that new software tools and methodologies are being investigated, including simulation, higher-level programming environments and machine learning.

The common platform poses its own problems for the organisation of the league. The Sony Aibo is a highly sophisticated robot available to teams at a relatively modest cost. The league has received exceptional support from Sony

but inevitably, new models will be produced and older models discontinued. Thus, teams must update their platform every two or three years. To avoid too costly a transition, it may be necessary to tolerate some diversity in the models of robots. However, to preserve the ability to share code, this diversity should minimised.

Considerations for the future are that if a humanoid robot becomes available at a reasonable cost would a new league be formed along the same lines as the four-legged league? What would be the relationship of this league with the present humanoid league and would there be a reason to continue the four-legged league? Considering the difficulties that most leagues have with unpredictable lighting, at what point can we consider outdoor games?

9 Simulation League towards 3D (by Martin Riedmiller)

The major novelty in the soccer simulation league is the development of a new simulator.

The simulator system will be built from scratch and is currently under development. Its main goal is to provide a more realistic simulation of real robots in order to bridge the gap between the real-robot leagues and simulation league. The concept comprises a 3D modelling of the environment, a modular approach that allows to design individual robot actuators and sensors, a more realistic handling of timing issues and collisions. The simulation of the physics will be based on the ODE library.

Due to the modularity and flexibility of the new simulator, it will be possible to eventually simulate even very specialized robots. Therefore, the core simulation system could eventually become the base for simulation of robots through all the leagues - including the humanoid leagues.

A main challenge for the transition phase will be to get the level of abstraction right. The simulator league must still focus on its main goals - the development of scientific approaches for mid- and high-level control (e.g. multi-agent coordination) - without bothering too much on low level (close to hardware) problems. In the ideal case, the new simulator will offer various interfaces that allow to tackle control problems on various levels of abstraction, ranging from a close-to-hardware view to a reasonably abstract view that directly allows to deal with mid-level and high-level issues. Providing such a high-level interface (comparable to the one of the current soccer server interface or even more abstract) will also raise the attractiveness for researchers that are more interested in AI than in robotics or control.

The current schedule is

2004, January : First version of new soccer simulator available, discussions.
2004, June: Tournament at RoboCup 2004, in parallel to a 'classic' (2D) simulator tournament.
2005: Tournament at RoboCup 2005, in parallel to a 'classic' (2D) simulator tournament.
2006: New simulator becomes the standard soccer simulation system

The weighting of the classic (2D) and the 3D simulator competition in 2004 and 2005 will depend on the status of the implementation and the number of teams participating for the respective competition. As an outlook for future directions: With simulated humanoid tournaments, Simulation league will become close to real humanoid robots.

10 **Vision SIG** (by Andrea Bonarini)

Vision is the primary input for robots, not only in RoboCup, but also in many applications involving mobile and fixed robots. The vision task in real world mobile robot applications should be performed in a short time, so to provide input to the control system, but at the same time should contribute to a reliable and rich world model.

RoboCup offers an important testbed in all the real-robot leagues to test vision algorithms and sensors.

The RoboCup community is working on vision aspects as part of the whole activity of implementing playing robots. The primary aim of this SIG is to support the research activities concerning perception by vision systems in RoboCup. In all the leagues working with real robots, people has to implement effective, real-time, vision systems, facing many different problems which are also of great interest for applications outside RoboCup.

Among the faced topics are:

- color vision,
- real-time algorithms for image analysis, object recognition, localization, and panoramic (omnidirectional) vision,
- stereo (multicamera) vision,
- multi-sensor fusion.

To promote research in vision within and outside RoboCup, the SIG has started the following activities.

- Maintaining a mailing list. A mailing list for this SIG has been created as vision@RoboCup.biglist.com. You may connect to http://www.RoboCup.biglist.com/vision/ and follow the instructions to be added to the list. You may also find there archives of past messages.
- Maintaining a web-based repository of data and tools, available as http://RoboCup.elet.polimi.it/SIG-Vision/.
- Promoting and maintaining a forum to discuss and support the development of vision related topics.
- Organizing vision workshops and special sessions, together with researchers from outside of RoboCup, at major conferences like CVPR, ECCV, ICPR.
- Organizing special events at RoboCup workshops/games. The SIG will work with organizing committees to organize annual events that emphasize research in vision.

- Encouraging community-based development of general, re-usable, code and standards, to facilitate comparative evaluation and to accelerate research, mainly for newcomers on this topic. See the repository and the forum on the web site.
- Proposing rule modifications to steer research within RoboCup, for instance reducing the role of color, or improving the role of other features.

At the last meeting of the SIG in Padova, people present have agreed to share code and experience in developing vision systems used in RoboCup. The web site has been updated accordingly. In particular, we have decided to host also a repository of open questions and problems, so that newcomers or people not wishing to be too much involved in vision could find help from the SIG.

We also have decided to focus on some problems, stating a sort of forum to brainstorm about their possible solutions and to share experiences. The problems currently on the table are mentioned here below.

- Adaptive color classification. Probably, from 2004 many leagues will play on fields with uneven light coming from different sources. Adaptive color calibration may play a key role to face this issue, and its real-time solution is still an important open problem in the whole vision community, with important impact on industrial applications
- Spot light and shadows. On the way to play with natural light, coming from a directional source, the sun, it may be interesting to work with a single spot light, providing, for instance, shadows, which may be considered an important element instead of noise.
- Knowledge and interface between sensors and world model. How to interface the vision system to behaviors? Which kind of information is passed? Would it be useful to include knowledge in the vision system or this should only provide raw data and leave the conceptualization to a world modeller? Is a conceptualization useful at all?
- Vision-based self localization. Is self-localization needed in RoboCup? Why? How do you self-localize your robots? Do you fuse data from different sensors? Which kind of algorithms do you use? Do you merge information from different robots?

Finally, we have decided to promote the implementation of benchmarks on the above and maybe other topics, so to focus and base research with a scientific approach, which is often forgot in the competition activities.

A suggestion of the SIG to the Executive Committee has been the implementation of specific competitions, or scientific challenges common to different leagues, so to provide a stimulus to focus research activities on specific, relevant issues.

11 Multiagent Learning SIG
(by Use of Communication with Peter Stone)

Participants from all the soccer leagues and at least rescue simulation are participating. Some benchmark tasks for learning were proposed and discussed with the

goal of making them usable by people outside of RoboCup. Potential challenges were proposed that could be applicable across the leagues.

- The keepaway task is already used for learning in simulation, and may be immediately possible in the Smallsize League. Hopefully it can be incorporated into other leagues as well.
- A multiagent goal-scoring task has been proposed and implemented in a Midsize League simulator (by Alex Kleiner).
- A further proposal could concern a challenge task for vision learning that would require teams to be able to automatically calibrate their vision. They would need to send in their code for the challenge task BEFORE seeing the lighting conditions at RoboCup.

A big challenge is defining tasks that not only CAN be learned, but that REQUIRE learning for success. There is a common understanding that a RoboCup team with learning has advantages over one without. But the best way to create a competent team quickly is still to hand-code it. That's true for most subtasks that we can think of. By 2010 we hope to have a well-defined and popular suite of challenge tasks both for RoboCuppers and for the general ML community who are not RoboCuppers.

12 **Other SIGs** (by Use of Notes from Thomas Christaller)

SIG Configurable and Modular Robotics:
A web page using wiki-web software was installed to make it easy for everybody to contribute without any administrative overhead. It serves for e.g.

- Setting up shopping infos in a data base.
- Mailing list.
- Steering committee.

SIG Simulation Tools for Real Robots:
Many teams make use of simulation tools. Current simulation league simulator is not useful to robot teams (but cf. M. Riedmiller's section on Simulation League above). Research challenges are e.g.

- realistic dynamics,
- configurability, extensibility,
- vision as a primary sensor.

The major goal is an open source simulator with ODE as technical basis. It is intended to be useful outside RoboCup, too.

13 **Final Remarks** (by Hans-Dieter Burkhard)

The workshop took place in the beautiful little village Blaubeuren, near Ulm in the southern part of Germany. Blaubeuren has a well-preserved medieval

architecture, and it is especially known by the circular Blautopf ("Blue Pot"), the legendary underground source of the river Blau. This karst spring is among Germany's most mysterious nature prodigies, and it is the setting for the "Legend of the Beautiful Lau". Thanks goes to Gerhard Kraetzschmar for proposing and organizing the meeting in Blaubeuren.

Two days if intensive work helped to clarify recent developments and to outline future challenges and requirements. The main goal of RoboCup is scientific research, hopefully with useful applications. In several countries, funding is directly connected with impacts for such applications. In fact, the aim of our community is not to build special purpose soccer machines, but to come up with new results and new solutions for a broad range of problems. The competitions serve for evaluation and for demonstration of successful developments. The vision of the 2050 year goal serves for the identification of problems which are important for Robotics and AI. Therewith, RoboCup stands for a community with a longterm project.

Thomas Christaller has compiled a list of general capabilities that a humanoid soccer robot has to met for the 2050 year goal:

- Playing over two times 45 minutes plus possible extensions of 2 times 15 minutes.
- Running more then 20 km during one game.
- Playing under severe weather and ground conditions sunshine, rain, snow, slippery, uneven ground, different and changing ground conditions.
- Controlling the ball with nearly all parts of the body (excluding arms and hands).
- Jumping, falling down, touching, body check.
- Artistic movements lay persons are uncapable to do.
- Size, weight, and force similar to an adult man (170cm, 65kg, 100m/12sec, 20m/sec ball speed).
- Forecasting and recognizing intention of movements before it is "manifest".
- Knowing team members individually.
- Knowing members of opponent teams.
- Knowing a lot of past/historical games.

Nobody knows today, if these problems can be solved at all. Most difficult problems may be

- Body construction and energy.
- Body control towards artistic/professional movements.
- Forecasting intended behaviour/movements of other players. (opponent as well as team members)

RoboCup research and competitions will help to clarify the related problems step by step. That forces us to define new goals year by year. The roadmap will be further discussed on the symposium in Lisbon 2004, and the next workshop of the Executive Committee is planned for autumn 2004.