An Overview of RoboCup-2002 Fukuoka/Busan

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■ This article reports on the Sixth Robot World Cup Competition and Conference (RoboCup-2002) Fukuoka/Busan, which took place from 19 to 25 June in Fukuoka, Japan. It was the largest RoboCup since 1997 and held the first humanoid league competition in the world. Further, the first ROBOTREX (robot trade and exhibitions) was held with about 50 companies, universities, and institutes represented. A total of 117,000 spectators witnessed this marvelous event. To the best of our knowledge, this was the largest robotic event in history.

The Sixth Robot World Cup Competition and Conference (RoboCup-2002) Fukuoka/Busan took place from 19 to 25 June in Fukuoka, Japan. Competitions were held at Fukuoka Dome Baseball Stadium from 19 to 23 June followed by the International RoboCup Symposium on 24 to 25 June.

RoboCup is an attempt to foster intelligent robotics research by providing a standard problem, the ultimate goal of which is to build a team of 11 humanoid robots that can beat the human World Cup champion soccer team by 2050. It's obvious that building a robot to play a soccer game is an immense challenge; readers might therefore wonder why we even bother to propose RoboCup. It is our intention to use RoboCup as a vehicle to promote robotics and AI research by offering a publicly appealing but formidable challenge (Asada et al. 1999; Kitano et al. 1997).

A unique feature of RoboCup is that it is a systematic attempt to promote research using a common domain—soccer. Also, it is perhaps the first robotic event to explicitly claim that the ultimate goal is to beat the human World Cup champion team. One of the effective ways to promote engineering research, apart from specific application developments, is to set a significant long-term goal. When the accomplishment of such a goal has a significant social impact, we call it a Grand Challenge Project. Building a robot to play soccer is not such a project, but accomplishing this task would certainly be considered a major achievement in the field of robotics, and numerous technology spinoffs can be expected during the course of the project. RoboCup is definitely a landmark project.

Since the first competition in 1997 (Kitano 1998), RoboCup has grown into an international joint research project in which about 3000 researchers from 30 nations around the world participate (table 1, figure 1). It is one of the most ambitious projects of the twenty-first century. RoboCup currently consists of three divisions: (1) RoboCupSoccer, a move toward the final goal; (2) RoboCupRescue, a serious social application of rescue activities for any kind of disaster; and (3) RoboCupJunior, an international education–based initiative designed to introduce young students to robotics.

RoboCup-2002 was the largest competition since 1997 and showed its epoch-making new standard for future RoboCups. One thousand four team members from 188 teams from 30 nations around the world participated. It included the first humanoid league competition in which 13 teams from 5 nations participated. Further, the first ROBOTREX (robot trade and exhibitions) was held, with about 50 compa-

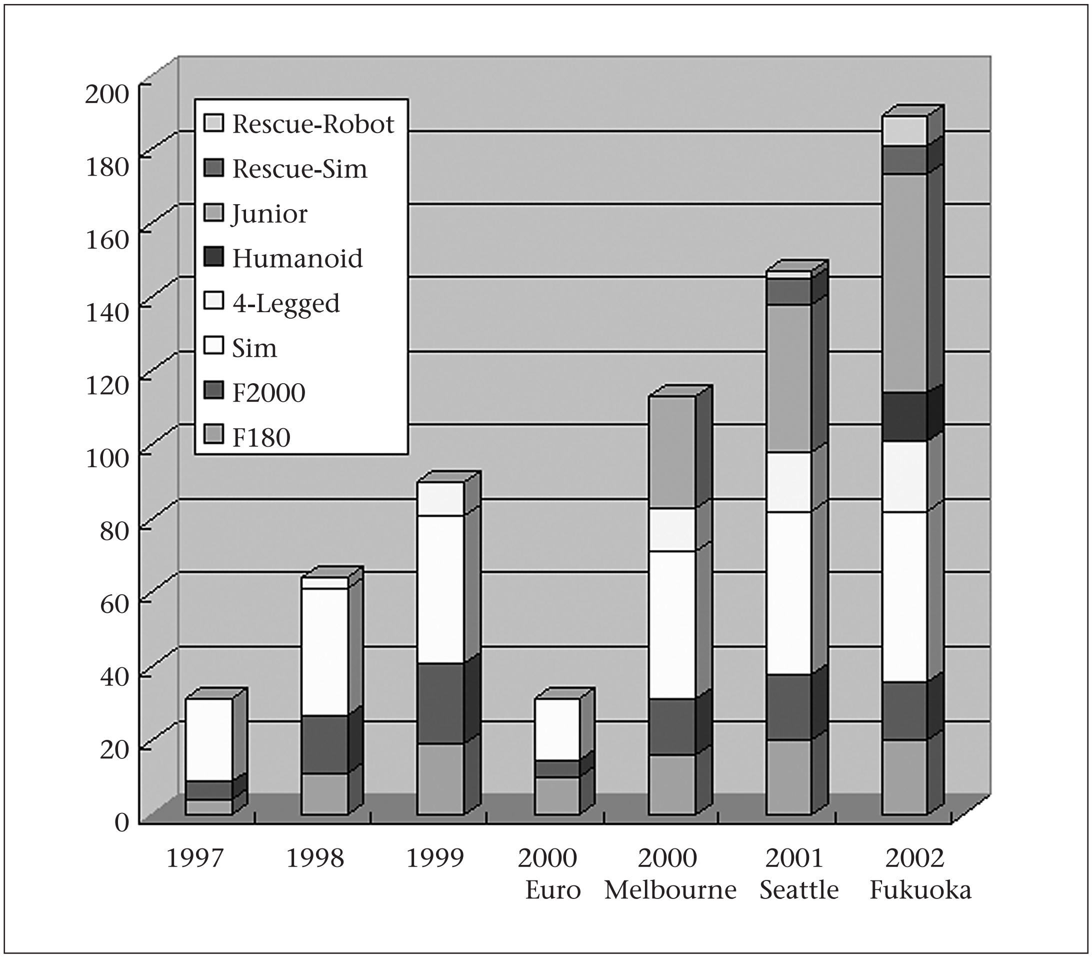

Figure 1. The Number of Teams in Each League.

nies, universities, and institutes represented. Eventually, a total of 117,000 spectators witnessed this marvelous event. To the best of our knowledge, this was the largest robotic event in history. Figures 2a and 2b show the dome and competition site. Figure 3 shows all the 2002 participants.

This article reports on RoboCup-2002; for more details, refer to Kaminka, Lima, and Rojas (2003). Reports and symposium proceedings of the past RoboCups are also available (Asada and Kitano 1999; Asada et al. 2000; Birk, Coradeschi, and Tadokoro 2002; Coradeschi et al. 2000; Noda et al. 1998; Stone, Balch, and Kraetzschmar 2001; Stone et al. 2001; Veloso, Pagello, and Kitano 2000; Veloso et al. 2002).

RoboCupSoccer

RoboCupSoccer has the largest number of leagues: (1) the simulation league, (2) the small-size robot league, (3) the middle-size robot league (held since the first RoboCup in 1997), (4) the Sony four-legged league (an official league since 1999), and (5) a humanoid league. The humanoid league is a big challenge with a long-term, high-impact goal, which could generate major spillover effects. The industrial, scientific, and educational impacts could be enormous (Kitano and Asada 2000). Table 2 summarizes the settings and characteristics for each league.

Simulation League

In the simulation league, the RoboCup SOCCER SERVER provides a standard platform for simulated soccer teams to play against each other over a local network (figure 4). Each team connects 11 player programs and possibly a coach client to the server, which simulates the two-dimensional (2D) soccer field and distributes the sensory information to the clients. Besides the team clients, the RoboCup soccer monitor or other visualization and debug tools can be connected as a client to the server to provide 2D or 3D visual information or information

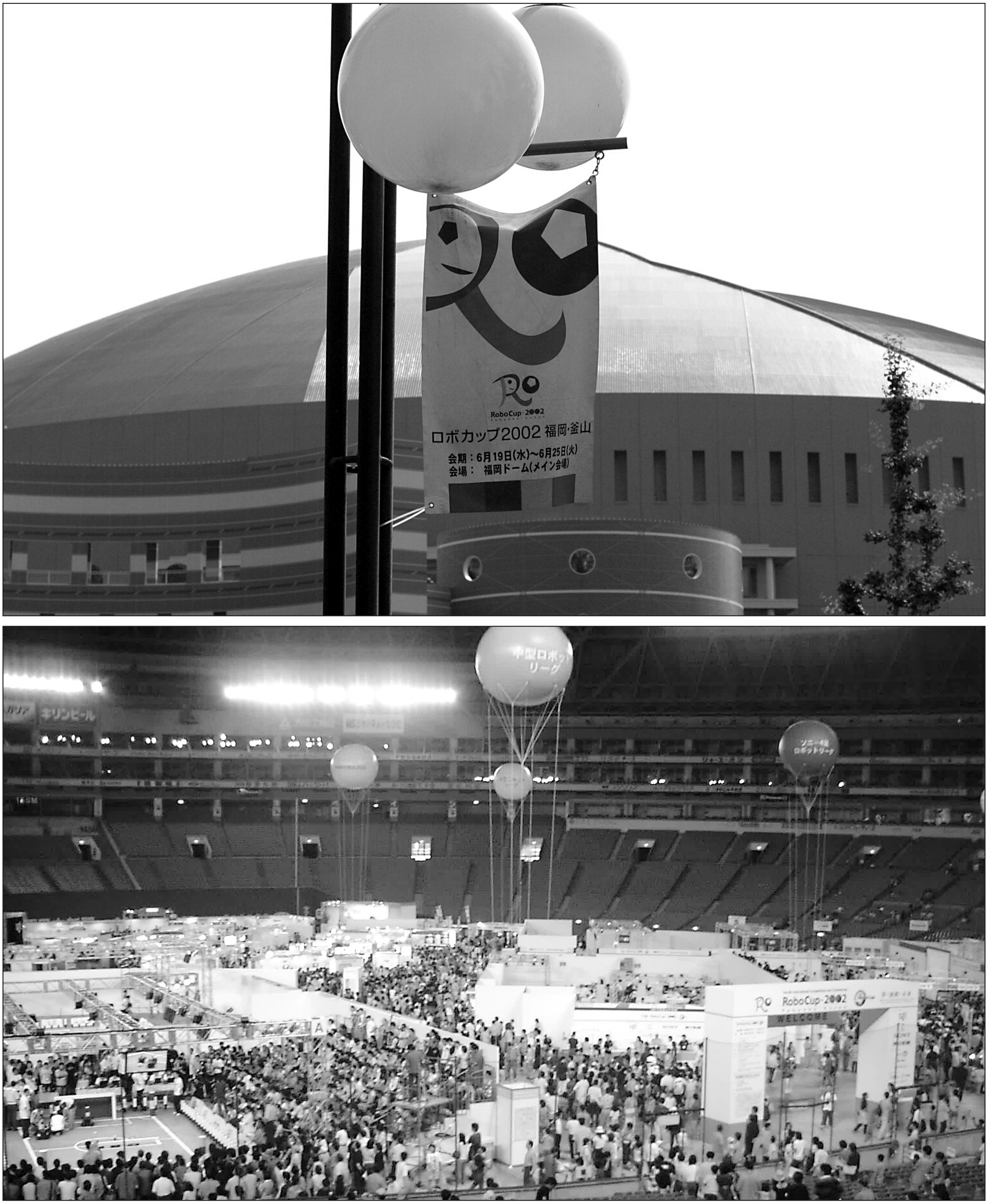

Figure 2. The Competition Site.

Top: The RoboCup-2002 flag and the dome. *Bottom:* Inside the dome. *(Photographs courtesy Kaori Yoshida.)*

Leagues	1997	1998	1999	2000	2001	2002
RoboCup Soccer						
Simulation	Official	Official	Official	Official	Official	Official
Small size	Official	Official	Official	Official	Official	Official
Middle size	Official	Official	Official	Official	Official	Official
Legged		Exhibition	Official	Official	Official	Official
Humanoid				Exhibition	Exhibition	Official
RoboCupRescue						
Simulation				Official	Official	Official
Real robot				Exhibition	Official	Official
RoboCup Junior			Exhibition	Official	Official	Official

Table 1. Evolution of RoboCup Initiatives.

Leagues	Robot Size	Onboard Sensing	Offboard Sensing	Number of Players		Challenges and Issues
Simulation	n/a	Yes	Coach agent	11	n/a	Coach competition, visualization
Small Size	Diameter < 18 cm	Allowed but used infrequently	TV camera on ceiling, color markers on the players	5	2.4 m x 2.9 m	Navigation, shooting, passing
Middle Size	Diameter < 50 cm	Yes; color uniform and color corner poles	No	4	5 m x 8 m	Dribbling, cooperation
Legged	AIBO	Yes; color uniform, six color poles, and wireless communi-cation	No	4	3 m x 4.5 m	Pattern recognition, collaboration, and ball collection
Humanoid	Height approxi-mately 40, 80, 120, or 180 cm	Yes	Yes	1	7.2 m x 10.4 m	Standing on one leg, walking, penalty kick, free performance

Table 2. RoboCupSoccer Leagues and Characteristics in 2002.

such as game statistics and analysis for the spectators.

Teams and Tournament In the 2002 simulation tournament, 42 teams participated, with the traditionally strongly represented countries of Japan, Germany, and Iran each having seven or more teams. Other teams came from China, Australia, the United States, the Netherlands, Russia, Poland, Belgium, and—for the first time—India. The tournament was organized into a two-round, round-robin stage followed by a double elimination round for the eight strongest teams (quarter-final level). In the first round, the groups had five to six members, the first two being seeded according to their performance in RoboCup-2001 and other official tournaments since then. The best three of each group proceeded into the second round, where each group had six members. Only the best two teams from each group in the second round proceeded into the double elimination. This configuration enabled most teams to have a large number of encounters and ensured that no strong team would be eliminated early on. The success of this concept was indeed corroborated by the performance of the eight teams surviving to the elimination round.

The tournament was won by the champion of 2001, TSINGHUAEOLUS, from Tsinghua University in Beijing (China), that even more clearly than last year, dominated the tournament. TSINGHUAEOLUS possessed skills, especially ball handling, of a very high quality. Precise passing and quick and effective positioning were the most visible capabilities of the team. Internally, TSINGHUAEOLUS uses a task-decomposition mechanism that assigns different parts of the

Figure 3. All the 2002 Participants. (Photograph courtesy, RoboCup Federation.)

Figure 4. Soccer Simulation Site. (Photograph courtesy RoboCup Federation.)

task to different agents and resolves conflicts using a global utility function (Jinyi and Yunpeng 2002). Here, a mutex mechanism is applied to the utility function to ensure that no two mutually inconsistent actions are taken. This mechanism is applied in the selection of defense roles, for example. Symmetry breaking is used to resolve ambiguous cases. Second in the tournament was the team EVEREST (Yang et al. 2002) from the Beijing Institute of Technology. Their code was based on TSINGHUAEOLUS 2001; their playing style was similar, although they were clearly surpassed by the champion but superior to a large number of strong teams. Team BRAINSTORMERS from the Universities of Karlsruhe and Dortmund (Germany) placed third, thereby maintaining the same consistent high-class performance that they have displayed throughout the last years' tournaments. An increasing number of BRAINSTORMERS's capabilities have been trained using reinforcement learning, but this year, the team added a learned behavior for selecting the best pass receiver to the repertoire (Riedmiller et al. 2002).

All in all, the playing level of the tournament showed increased and consistent improvement over last year's tournament. More professional and scholarly approaches are being used by a wider number of teams. Modern techniques of AI and machine learning (for example, particle swarm localization [Kok et al. 2002] as used by team TRILEARN from the University of Amsterdam [The Netherlands] or reinforcement learning as used by the BRAINSTORMERS) have become standard approaches; their use is no longer restricted to specialized teams but has entered the domain of general know-how. Moreover, beyond implementing theoretically defined AI tasks, the simulation league offers a complex domain that forces the teams to adapt theoretical designs to a concrete and nontoy scenario.

This year's presentation tournament was won by the SBCe TEAM ASSISTANT (Nazemi et al. 2002) from Shahid Beheshti University (Iran). It was not a visualization tool that would create an appealing visual presentation of the simulation games but a debugging software that would allow team developers to accurately control and analyze the player behaviors in specific game situations.

3D and Internet Competitions Since the first RoboCup simulation league competition, the RoboCup SOCCER SERVER has constantly been evolving to keep both competition and research aspects interesting. The simulation league is the league in RoboCup with the most soccerlike matches, with the rules adhering more closely to the official Federation Internationale de Football Association (FIFA) rules than in any other RoboCup league. To further push the envelope and keep the overall RoboCup goal in mind,[1] discussions about developing a 3D physical SOCCER SERVER began during the competitions. It is hoped that preliminary 3D competitions can be held during RoboCup-2003 in parallel with the classical 2D competition.

To continue the possibility of testing teams and provide a competition-like setting all year long, the Simulated Soccer Internet League was established after RoboCup-2002. Developers install their teams on the competition machines, hosted at the University of Koblenz, using the internet. The server and teams are started automatically, but other than during the RoboCup competitions a slowed-down server is used to keep the number of required machines low. Each time an internet league round is over, developers can download the recorded log files and use them for analysis of their team's behavior. Another novelty is the availability of the RoboCup competition matches in flash file format, so that RoboCup-2002 simulation league matches can be replayed with simply a web browser using a flash plugin.[2]

Small-Size Robot League

Never in the history of RoboCup has a robot soccer final been played with such speed and control, as demonstrated in the small-size league final between champions BIG RED (Cornell University) and FU-FIGHTERS (Free University of Berlin, Germany). Needless to say, there have been significant advances in the state of the art in the small-size robot league (figure 5).

In the small-size robot league, global perception allows the teams to focus primarily on robot control and multirobot teamwork. At RoboCup-2002, many advances were made on multiple fronts. Progress was made in robot control at high speeds, innovative mechanisms for ball control, multiple sensor fusion (that is, multiple cameras for tracking), and one of the first adaptive strategy engines to be used in any robot league. Using a combination of innovative mechanical and control techniques, both leading teams produced robots able to accelerate at phenomenal speeds. Exact figures are not available, but accelerations of $5m/s^2$, with peak speeds above $2m/s$, would not be surprising. FU FIGHTERS utilized custom-built omnidirectional wheels to achieve high levels of traction, and Cornell utilized a new four-wheel approach to gain additional stability under acceleration load.

The final results of the competition highlight the two key features of the competition:

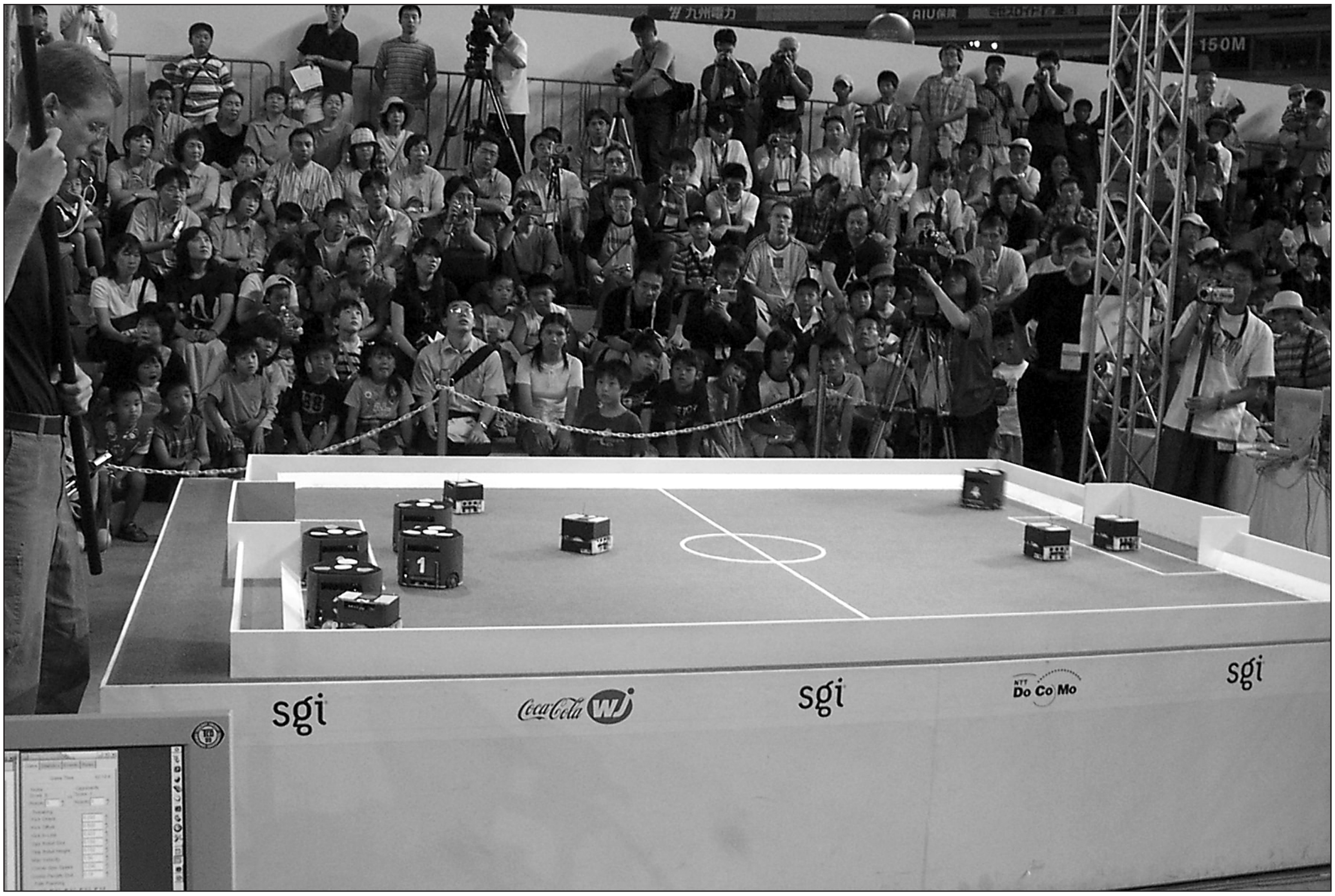

Figure 5. A Game Scene from the Small-Size Robot League.

(1) a good team is an integration of many components and (2) the general level of the competition has improved dramatically during the course of RoboCup. Although speed played a crucial role in the competition, it is interesting to note that the competition winners did not win the navigation challenge, one of the new challenge events introduced this year. (The navigation challenge required a robot from each team to navigate through a fixed, but unknown, obstacle field as quickly as possible. The other challenges were shooting and passing). The champion BIG RED was fast and also used a new and improved dribbler mechanism (a rolling bar covered in rubber that spins the ball backwards and, therefore, controls it) to move around the field at speed and still stay in complete control of the ball. In contrast, other teams tended to either be fast or be able to manipulate the ball well, but not both. Virtually all the teams had working hardware systems able to play a game of soccer that would have been competitive in prior RoboCup competitions, a true testament to the overall advances in the level of the competition.

To reach the lofty goals of RoboCup, the small-size–league competition must constantly evolve in synchronicity with the research developments made by competition teams. For 2002, a number of changes were introduced to the competition. Most notably, challenge events moved toward regional qualification competitions, and a referee box was introduced to automate team responses to referee commands. For 2002, teams had to automatically start and stop their robots using the referee box signals. It is hoped that for 2003, entire games will be autonomous (that is, no human intervention) rather than just active play. Such changes to the competition will be expected to continue to make this league a hotbed for future robot intelligence developments.

Finally, new open-source collaborative development efforts are under way to release a 3D realistic dynamics simulator, a variety of real-time vision servers, and releases of 2002 game software. The small-size–league committee hopes that these programs will further contribute toward the development of this league and introduce new competitors to this exciting game.[3]

Figure 6. A Game Scene from the Middle-Size Robot League.

Middle-Size Robot League

In the middle-size robot league, the major rule modification for 2002 was wall removal: No walls delimited the field, only the white line. A range of black and white poles was around the field, 1 meter outside. Some teams had programmed their robots to recognize the border lines and maneuver to try to keep the ball inside the field; this operation is quite difficult in this league because of the limitations on the ball-bearing device. Some teams equipped their robots with a special device, able to keep the ball in contact with the robot body and still keep it rotating (as defined in the rules), but their performance in keeping the ball inside the field was in general worse than that of traditional, well-controlled robots. An important improvement achieved by almost all the teams was the control of contact with other robots: Almost all were able to detect other robots and act appropriately to avoid charging and still show effective behavior. Almost no team was able to reach the initial positions autonomously, thus putting in evidence the limits of the current self-localization methods (table 3).

The introduction of scientific challenges produced some interesting improvements. The first challenge consisted of dribbling around two poles placed in fixed positions, maintaining control of the ball, and then kicking it into the goal. Only one team was able to perform the trial without touching the poles, but another one was able to dribble around the poles and score

Challenge Title	Activity	Aims
Challenge 1: Dribbling	Dribble the ball between two fixed poles and score a goal.	Improve ball control and obstacle avoidance.
Challenge 2: Cooperation	Freely demonstrate cooperative tasks.	Identify interesting and feasible cooperative tasks.

Table 3. The Middle-Size Robot League Challenges.

the goal in about 10 seconds, just hitting a pole by millimeters. This result showed that it is possible to have good control with the present shape limitations but also that teams have to work hard to obtain control. The second challenge was a free demonstration of cooperative behavior. Five teams proposed ball passing, but only one was successful, and the ball passing was done in the direction of the incoming teammate. Other teams proposed distributed sensing (a blind robot could effectively move by using information coming from others) as well as dynamic role changing: A broken goalie was automatically substituted by a teammate (figure 6).

In general, one of the major open problems is still reliable vision; we are still too dependent on calibration and settings. Many teams complained about shadows on the field; the color of the ball, which was slightly different from that of 2001; and illumination coming from light sources other than those on the field. This theme will be a focus for our efforts in the coming years, with the aim of being able to play with natural light coming from windows. Other challenges for the next years will be the removal of known references around the field, such as the pole ranges mentioned earlier; the colored goals, possibly substituted by netted ones; and the substitution of the orange ball with a more common black and white ball. Communication was still a problem because of radio interferences, and some teams are planning to develop techniques to run a match without explicit communication between teammates or use communication media that is more natural, such as sounds or gestures.

In some situations, it was evident that the robots did not implement Asimov's first robotic law,[4] and referees were injured by robots. Probably, in the future, we will introduce an automatic way to communicate referee decisions to the teams (such as the referee box in the small-size league), thus limiting the presence of referees on the field; as it stands now, we are still far away from having safe robots able to play with humans, and work should be done in this direction.

Four-Legged Robot League

In 2002, the field size was enlarged to about 3 meters x 4 meters, and the number of robots in each team was increased to 4 (figure 7). These changes were expected to encourage passing and other team plays. In addition, a wireless communication system was introduced with a standard wireless local area network (IEEE 802.11b), and each robot was allowed to communicate with its team's robots. Thus, a robot could recognize its team robots' positions using the wireless communication, which makes the passing behavior easier.

The results of the competition showed that some of our expectations were achieved. In 2002, we had 19 teams in the championship. Teams from the University of NewCastle (Australia), the Georgia Institute of Technology, and Technologico de Monterrey (Mexico) were new participants. The winner of the championship tournament was CMPACK02 of Carnegie Mellon University (CMU). This team developed stable and fast locomotion and color vision as individual technologies. In addition, the team efficiently used the wireless system for cooperative behaviors. All the participants from Australia—University of New South Wales, University of Newcastle, and University of Melbourne—placed second through fourth. Both the final and the third-place games were very exciting, and from an entertainment point of view, they were of very high quality.

In addition to the championship tournament games, there were three technical challenges: (1) pattern analysis, (2) collaboration, and (3) ball collection. The pattern-analysis challenge was to recognize patterns with black and white checks. The challengers did not know the size of the patterns shown or the direction in which to find them. One of the objectives of this challenge was to replace the colored items, such as a landmark, with these black and white patterns so that we could remove the strict light tuning for the setup. No team was able to accomplish the task, but three teams (CMU, the University of New South Wales {UNSW], Australia, and the University of Washington) recognized two patterns. The collaboration challenge was to have two robots move a color-painted bar. This task required collaboration between the two robots. Three teams (UNSW, CMU, and University of Science

Figure 7. Just before the Game of the Four-Legged League.

and Technology of China [UTSC] were able to complete the task. The third challenge was to have two robots gather many balls in the goal area. This task required basic skills for the legged robot league, which are to find the ball and move the ball into the goal. However, when only a few balls remain, the two robots have to avoid pushing the same ball against each other. UNSW was able to achieve the complete task and won the total challenges.

There was an important change for the Sony four-legged robot league in 2002. Sony released OPEN-R SDK for consumer users so that anyone can develop their own software for the AIBO ERS-2XX series. Now, the Sony four-legged robot league is an open-entry league. Any team can participate in RoboCup-2003. Because of space and schedule limitations, only about 20 to 24 teams can be selected for the RoboCup championship event; however, local competitions such as the Japan Open, the American Open, and the German Open will be held. When this article was being written, the committees were discussing a qualification process, which should be finalized by the time this article is published.[5]

Humanoid League

The first humanoid league was held this year with 13 teams from 5 nations, many more teams than we had expected. The teams included one team of two hobbyists from Japan; three teams from Sweden; two teams from Singapore; and single teams from Australia, New Zealand, and Denmark (figure 8). A variety of different humanoids participated, all of varying size, control architecture, and purpose. According to the size of the humanoids, we classified all robots into four classes: 40, 80, 120, and 180 centimeters. To encourage the participating teams, we did not strictly apply the size regulations. For example, the largest one was MURPHY from Sweden. Its

Figure 8. All Participating Humanoids.

height was 220 centimeters, and it weighed 130 kilograms.

We would like to guide development toward fully autonomous humanoid robots. Therefore, we measured so-called performance factors for the different dimensions with regard to autonomy (external power cord, external control, remote control by human). Each was 1.2, and if more than one was applicable, then they were multiplied (1.2, 1.44, 1.728, 2.0736). These factors were either used as a penalty factor (for example, in walking the time taken was multiplied by these factors) or a handicap (in penalty kicking, the score was divided by these factors). These factors worked quite well (with regard to the previously stated intention) and will certainly prefer the more autonomous robots but will also allow for semiautonomous robots if their performance is much better than that of the autonomous ones.

Because the gamelike competition using many humanoids was hard to realize because of the cost and the lack of robust control technology for humanoids that have so many degrees of freedom, we focused on the fundamental challenges such as one-leg standing, walking, penalty kick, and free style. The following paragraphs summarize these challenges.

Stand on one leg: This is definitely no problem for most of the humanoid robots, or it shouldn't be one, but it is a problem for humans! This ability makes for a wonderful entry if the audience is also involved. In Fukuoka, team members were asked to perform this challenge together with the robots.

Walking: The different physical heights of the robots were compensated for by the length of the course, which was made five times the actual physical height of the robot. The winner was NAGARA (height: 80 centimeters); its total time for the three trials was 3 minutes and 30 seconds. The team consisted of members of industry, the university, and the Gifu prefecture.

Penalty kick: This challenge is a sort of one-to-one (shooter versus goalie) competition. Again, the physical height of the striking robot (and also the goalie robot in the corresponding categories) was used to determine the distance between the ball and the striker, but the goals were only available in two sizes (40 centimeters and 80 centimeters in height). The shooter of each team had five trials during which the goalie of the opposing team tried to save the goal. After the five trials, the shooter and the goalie exchanged positions. Actually, most goalies simply stood still except for the Osaka University team whose goalie fell down trying to save the goal. In the 40-centimeter class, the Japanese hobbyist team FOOT-PRINTS won first prize, and in the 80-centimeter class, NAGARA again won first prize. The second prize in the 80-centimeter class went to the SENCHANS, Osaka University, which showed wonderful performances in both shooting and goal saving. Figure 9 shows the shooting scene in which the shooter stood on one leg, bent the body forward, and then kicked the ball.

Free style: All teams have three minutes to show their talent in free performance, such as a dance with music, an athletic performance, or an imitation of a human. The aim of this competition is not simply to show the performance of the humanoid robots but to act as a test bed for humanoid research in general by not limiting performances to the soccer domain. Consequently, this challenge turned out to be entertaining, as well as demanding, for the teams. The team SOUTHERN DENMARK gave an impressive performance of 11 Lego humanoids and became the first champion of the free style.

The best humanoid award was given to the team NAGARA that produced excellent achievements in all kinds of competitions. Louis Vuitton is sponsoring the traveling trophy for the coming 48 years until we reach the final goal.

Because this event was the first humanoid robot competition, everything was being tested. The following issues need to be addressed:

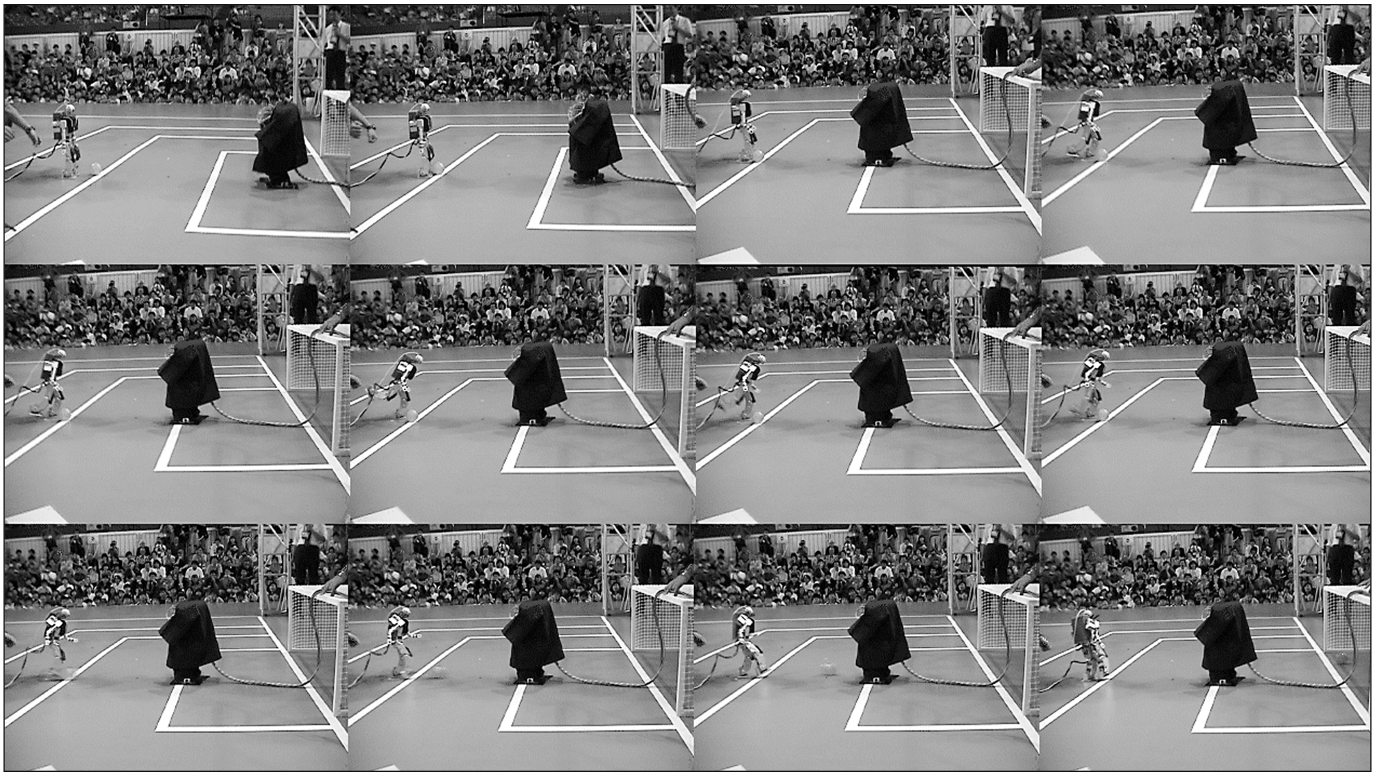

Figure 9. Osaka University's Humanoid Kicked the Ball into the Goal.

Performance factor: We used the same performance factor of 1.2 and applied it to all robots. What value should be assigned to which aspect?

Stand on one leg: Because it was difficult to discriminate the control between real-time sensor feedback and fixed open-loop feedback, it might be necessary to introduce a disturbance as a way of checking it.

Free style: To promote this challenge as a test bed for humanoid research in general, a standardized format for the competition seems necessary.

RoboCupRescue

The goal of RoboCupRescue is to provide solutions to socially important problems by applying technology created by RoboCup and other related research efforts (Kitano and Tadokoro 2001). The RoboCupRescue simulation league and the RoboCupRescue robot league were started in 2001.

RoboCupRescue Simulation League

A rescue team is composed of heterogeneous agents—fire brigades, ambulances, police, and their respective control centers. The rescue agents are connected into a virtual city on a computer network. When all disaster simulators are connected, a disaster occurs, and the agents save buried victims, extinguish fires, and repair roads in the disaster field.

Their rescue operations and cooperations are reflected by the following score:

$$V_{2002} = \left(P + \frac{H}{\mathrm{Hint}} \right) \times \sqrt{\frac{B}{B_{\max}}}$$

where *P* is the number of living civilian agents, *H* / *Hint* is the efficiency of operations of all rescue agents, and B / B_{max} is the portion of houses that are not burned. A team that gets the highest V_{2002} score wins a game. Programming rescue agents provides a concrete platform for studying multiagent research issues: incomplete information, no global system control, decentralized data, and asynchronous computation (figure 10).

RoboCup2002 Tournament After last year's competition, the following four proposals were adopted to provide (1) a geographic information system (GIS) file of a virtual city map, (2) tools to change parameters that specify magnitudes of earthquakes, (3) civilian agent modules that can specify actions as rules, and (4) a new traffic simulator that runs stably.

The first two proposals relate to the fact that disasters can occur at anytime around the world. Rescue teams are supposed to do rescue operations equally well at two cities, Kobe and

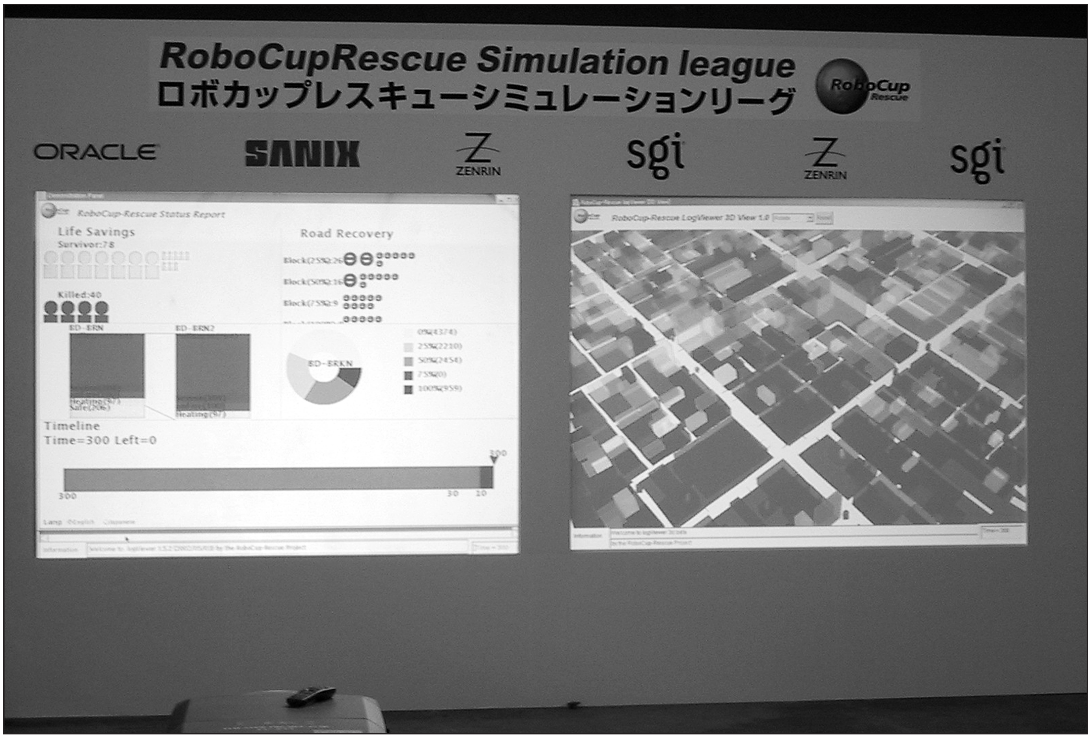

*Figure 10. A Rescue Situation Screen for the RoboCupRescue Simulation League.*R

a virtual city. Their operations are under unfamiliar conditions: They do not know which buildings and roads are collapsed. They also do not know the initial locations of civilians and fire ignition points, as was the case in 2001, thus requiring more planning under real-time constraints. Seven teams from 3 countries (15 teams from 6 countries at pre-registration) participated. The winner was ARIAN (Iran), YOWAI2002 (Japan) took second place, and NITRESCUE02 (Japan) placed third. It was interesting that the top two teams utilized different approaches to achieve agent cooperation. ARIAN made the most of communications among agents, and YOWAI2002 restricted communications. The difference comes from their image of, or experience with, disasters. ARIAN believed that communication such as a personal digital assistant or cellular phone should be used at disaster areas, but YOWAI2002 thought communication lines would be damaged by earthquakes and would not be available as usual.

Lessons Learned and Future Developments

Disaster rescue is one of the most serious social issues, involving large numbers of heterogeneous agents in a hostile environment. The differences between ARIAN and YOWAI2002 spotlight the fact that communication is only one of the key issues of multiagent systems; cooperation among rescue teams from various countries in real disaster situations is also important. These issues are important from both research and application viewpoints. In the future, communication between robot rescue agents and software rescue agents will be taken into consideration. Others issues such as evacuation from skyscrapers or underground shopping centers—disaster simulations—in other countries, are also items for future study and development.

RoboCupRescue Robot League

The objective of the RoboCupRescue robot league is to promote the research and development of practical robotic solutions for search in crushed buildings such as at earthquake disasters.

Ten teams from five countries participated in the RoboCupRescue robot league in 2002, as shown in table 4. Most robots were remotely teleoperated and had limited autonomy. Because of the complexity of the problem, fully autonomous robots are not practical—yet. Adjusted autonomy, shared autonomy, and autonomy for human interfaces are suitable in the application of AI to the real disaster problems.

Three sites representing earthquake disasters were created by Yuki Nakagawa (National Museum of Emergent Science) following a standard proposed by Adam Jacoff (National Institute of Standards and Technology). A

Competition

Team Name	Affiliation	Characteristics
HANIP Rescue Robot Team	YSC (Iran)	Crawler type, large
IUB Team 2002	International University of Bremen (Germany)	Baggy type, balloon camera
KAVOSH	Javan Robotics Club (Iran)	Two crawler types, periscope camera
Kingston Fire Brigade	University of Auckland (New Zealand)	Tire type, autonomous, small
MARB	Tokyo Institute of Technology (Japan)	Two crawler types, fast
SCARABS	New Roads School (USA)	Tire type, wired, high school team
Sharaf Rescue Robot	Sharif University of Technology (Iran)	Two crawler types, crawler mechanism
UVS-IV	Kobe University (Japan)	Two crawler types, mapping

Demonstration

Team Name	Affiliation	Characteristics
MINORI 2002	Nippon Institute of Technology (Japan)	Crawler type
ZMP Sensorbot	ZMP, Inc. (Japan)	Crawler type, wired

Table 4. Participants in the RoboCupRescue Robot League.

Japanese-house field was developed as the orange zone. Types of disasters depend on countries and regions because local situations such as houses, streets, and styles of habitation are different. For example, pancake crush (pillars falling down and floors piling up like pancakes) was typical in the Turkey earthquake, but first-floor crush was widely observed at the Kobe earthquake in Japan. Futon mats caused serious problems in search and rescue operations in Japan. It is important to evaluate robots and systems under a wide variety of realistic situations, according to the local needs. The rubble-pile field simulated debris that was completely destroyed where gaps were so small that large robots could not enter.

Thirty dummy victims were distributed in the fields (on the surface, in lightly trapped conditions, in a void, or in a total entombment). Babies and adults were painted gray, simulating dirt, and could not easily be recognized by robot cameras. They emit living signals such as the heat of bodies, the sound of shouting, CO_2, and the motion of body parts, although they do not react to robots interactively.

The score is calculated by a function evaluating the number of victims found, positional accuracy, and the quality of maps generated. The number of robots and the number of operators are also considered to promote research in multiagent autonomous robots. When an operator declares that he/she found a victim, referees check the validity on site.

The following problems were observed as lessons of the competition:

First, ropes, strings, newspapers, towels, and futon mats obstructed the motion of the robots. They sometimes got caught in the crawler mechanisms and caused the robot to get stuck and derail.

Second, wireless communication sometimes caused serious problems. When the camera image was jammed, operators could not move the robots. Internet protocol connection was sometimes cut under the unstable wireless environment.

Third, localization was an important problem. Robots sometimes lost their way. They could not identify unique victims and found the same victims several times.

Fourth, reliability was important. Some robots had been damaged during transportation to the competition.

Fifth, the human interface had a major effect on performance. Practice and operator skill were also important.

The target of RoboCupRescue is not limited to this field setup. A wide variety of disasters happen, and robots are expected to be deployed in any situation. For example, humanitarian demining is an important issue in robotics, and RoboCup should contribute to the promotion of technology for this purpose. Continuous participation of teams in the competition will lead to an advance of necessary technology, just as in the soccer leagues (figure 11).

RoboCupJunior

The junior division of RoboCup is a project-oriented educational initiative that sponsors local, regional, and international robotic events for young students. The purpose is to introduce

Figure 11. MARR*, the Second-Place Winner of the 2002 RoboCupRescue Robot League.*

RoboCup to primary and secondary school children as well as undergraduates who do not have the resources to get involved in the senior leagues. The focus in the junior league is on education. The overriding mission is to create a learning environment for today, fostering understanding among humans and technology for tomorrow.

RoboCupJunior offers several challenges, each emphasizing both cooperative and competitive aspects. The initiative is designed to provide its participants with an exciting introduction to the field of robotics; a new way to develop technical abilities through hands-on experience with electronics, hardware, and software; and a highly motivating opportunity to learn about teamwork and share technology with friends. In contrast to the one-child–one-computer scenario typically seen today, RoboCupJunior provides a unique opportunity for students with a variety of interests and strengths to work together as a team to achieve a common goal.

In Fukuoka, the Third International RoboCupJunior tournament was held (RCJ-2002) (figure 12). As indicated by the number and range of registrations, the initiative has begun to explode in popularity. Fifty-nine teams from 12 countries participated (table 5). For the first time, the event attracted teams from a wide geographic area. In total, 240 students and mentors were involved.

RoboCupJunior offered three challenges. Teams of students built fully autonomous mobile robots to meet these challenges, preparing for months in advance both during and after school. In the dance challenge, one or more robots wore costumes and performed to music in a display that emphasized creativity. Judges rated the robots on multiple dimensions that included programming, construction, costume, choreography, creativity, originality, and entertainment value. Winners were declared within each category, and an overall winner is also chosen. In the soccer challenge, there were two levels: One-on-one soccer was an entry-level game,

Figure 12. RoboCupJunior-2002 Participants in the Dancing Challenge.

and two-on-two soccer was for more experienced teams. For both levels, teams of robots played games in a rectangular field, specially fitted with a gray-scale floor and an electronic ball to simplify vision and localization issues. The soccer games were played in two 10-minute halves, following a simplified version of the RoboCup small-size league rules. Almost all the teams used partially fabricated robotic kits, such as the Lego Mindstorms, the Elekit SoccerRobo, and the Fischertechnik Mobile robot.

Perhaps the most progress this year was shown in the dance event. Twelve teams participated, each demonstrating unique and creative ways of combining technology with art and music. Some teams' routines told stories. Many teams shared their country's culture through traditional dances, music, and costumes worn by both robots and students. Several teams built robots out of wood, such as puppets, and dressed and decorated them for the occasion.

In the soccer event, the entry-level one-on-one game was tried for the first time at the international tournament. A relatively small number of teams entered. As an exhibition, a new friendship game was introduced this year. Teams were paired, each team supplying one robot, and the pairs participated in two-on-two games. In this way, teams that brought either one or two robots were able not only to experience the added complexity of the two-on-two game but also to interact with other teams in a shared project.

Ongoing research studying the educational value of RoboCupJunior and robotics as a learning environment is being conducted by some of the organizers. Results of examining participants during the first two years were presented at the RoboCup Symposium (Sklar, Eguchi, and Johnson 2002), and it was this paper that received the Scientific Challenge Award.

RoboCupJunior-2002 faced new challenges in terms of the number of participants, language and cultural issues, and differences in attitude regarding the meaning and mission of the junior initiative. All events were conducted in English and Japanese. For the first time, the number of teams desiring to participate exceeded the number that the venue and time frame could accommodate. Some countries held national selection events to determine which teams could enter. This trend presents challenges for the future.

If all countries are required to send their "national champions," then how do new countries with little or no national following get involved? In a geographically large country, is it practical to hold a national championship? Emphasis on the competitive aspects go against the RoboCupJunior mission. How do we organize an internationally recognized event that is centered around a competition and still remain focused on education?

During 2003, regional events will be held in conjunction with various national RoboCup tournaments, such as the American Open, the Australian Open, the German Open, and the Japan Open. Information can be found on the web sites pertaining to each of these events.[6,7]

Country	Number of Teams
Australia	8
Canada	1
Denmark	1
Finland	1
Germany	5
Japan	29
Korea	5
Macao	2
Norway	1
Slovakia	1
Thailand	4
USA	1

Table 5. Countries Represented at RoboCupJunior-2002.

ROBOTREX

To promote the robot technologies necessary to achieve the final goal of RoboCup, we first introduced ROBOTREX (Robot Trade and Exhibition) in 2002 at the site of the sixth RoboCup. The main aim of ROBOTREX was to promote robotics research and development by providing the space for researchers and industry to meet each other. It also provided a place for the average individual to learn about the current technology and think about its future through experiences with robots (figure 13). A wide range of the most advanced robot technologies for perception, action, and intelligence should be evolved toward this goal.

Fifty companies, institutes, universities, and local governments participated. A variety of exhibitions displaying a wide range of applications, such as factory automation, security, care, and entertainment, were shown and enjoyed.

Symposium and RoboCup Milestones Panel

The International RoboCup Symposium, an annual event at RoboCup, was held 24 to 25 June, immediately following the RoboCup competition events. The symposium attracted approximately 300 researchers, some who participated in RoboCup and others who came for the symposium itself. The symposium was multidisciplinary, sporting research results in areas such as learning, planning and plan recognition, vision, robot localization and navigation, education, and simulation. Seventeen oral presentations were given, marking an acceptance rate of 22 percent. In addition, 21 short papers were presented in 2 poster sessions.

The 2002 RoboCup Symposium held a number of special events. Three papers were selected for awards signifying science and engineering excellence. A long-term milestone road map for RoboCup was discussed in a panel that included all the league chairs. Finally, there were five invited talks, two of which took place in a joint session with DARS-2002, the Sixth International Symposium on Distributed Autonomous Robotic Systems, also held in Fukuoka.

The RoboCup road-map panel was held to discuss recent and future work from the perspective of the year 2050 goal: Develop a team of fully autonomous humanoid robots that can win against the human World Soccer champion team. The RoboCup leagues started discussing the road map in 2001 (Burkhard et al. 2002). The panelists from the different leagues were asked to think about milestones in the following way: What do we need in 2040 to reach the 2050 goal? To reach this milestone in 2040, what do we need in 2030? The milestones for 2020 and 2010 can be defined with the view to 2030.

With this view, the panelists agreed that certain artificial conditions such as specified lighting, special colors, and walls will be removed in 5 to 10 years (with different dates in different leagues; the middle-size league removed the walls in 2002). It is necessary to start working now on better vision systems, and the style of playing has to be changed. RoboCup will go to outdoor fields in 10 to 20 years. The time of play will increase (forcing better power supply), and team sizes will gradually increase to 11 players. There will be convergences between the leagues with respect to the special purposes of humanoid robots and FIFA rules in the next 20 to 30 years. The simulation league will con-

Figure 13. Robovie Is Playing with Kids at ROBOTREX-2002.

tinue to work for about the next 20 years with the “abstract simulator” for the development of, for example, multiagent and learning techniques, providing additional features (3D, continuous time, more realistic noise) step by step. Common efforts with the people of the robot leagues will lead to a “realistic simulator,” where real robot scenarios with accurate physical modeling can be investigated by simulation. The first realistic simulations of humanoid players should be possible in about 20 years (with the help of more computational power).

Many of the milestones discussed require progress in fields very different from AI, including material engineering, power supply, mechanics, and artificial muscle and sensors. Other milestones pose significant, but more familiar, challenges, including integrated perception, planning, learning, vision, action selection, and multiagent collaboration and coordination. Combined efforts in all these fields will lead to new scientific and technological questions and new results; therefore, the RoboCup community will encourage interdisciplinary work.

In addition, the panel discussed the educational challenges facing RoboCupJunior in teaching children to build and work with robotic technology. The main events in RoboCupJunior will concentrate on national levels all over the world and need appropriate organizational structures. Existing gaps between ages and between genders should be closed.

RoboCupRescue has the vision for 2050 to build teams of robots that can autonomously act in collapsed structures to find victims and ascertain their conditions. It needs coordination with human rescuers and logistic agents. Rescue problems will challenge the RoboCup community to move toward unstructured environments and the solving of problems of perception, localization, and mapping as well as cooperation between humans and artificial systems.

Conclusion

RoboCup-2002 finished with great successes in the competitions, the exhibitions, and the conference. Many people, not only researchers but also ordinary people, especially kids, participated and enjoyed the entire event. RoboCup-2003 will be held in July 2003 in Padva, Italy.

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Notes

1. "Develop a team of robots that can win against the human soccer World Champion team."

2. The game files are available from the results section on www.uni-koblenz.de/~fruit/orga/rc02/.

3. For interested readers, the 2002 small-size league web site is located at www.cs.cmu.edu/brettb/-robocup.

4. Asimov's first law is "a robot may not injure a human being or, through inaction, allow a human being to come to harm."

5. If you have an interest in the Sony four-legged robot league, please visit www.openr.org-/page1_ -2003/ for more information.

6. For further information about RoboCupJunior, refer to www.robocupjunior.org.

7. Locate by starting at www.robocup.org.

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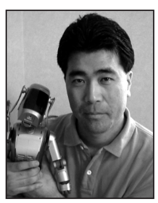

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