# Overview of RoboCup-2000

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**Abstract.** The Fourth Robotic Soccer World Championships was held from August 27th to September 3rd, 2000, at the Melbourne Exhibition Center in Melbourne, Australia. In total, 83 teams, consisting of about 500 people, participated in RoboCup-2000 and about 5,000 spectators watched the events. RoboCup-2000 showed dramatic improvement over past years in each of the existing robotic soccer leagues (legged, small-size, mid-size, and simulation), while introducing RoboCup Jr. competitions and RoboCup Rescue and Humanoid demonstration events. The RoboCup Workshop, held in conjunction with the championships, provided a forum for exchange of ideas and experiences among the different leagues. This article summarizes the advances seen at RoboCup-2000, including reports from the championship teams and overviews of all the RoboCup events.

## 1 Introduction

RoboCup is an international research initiative that encourages research in the fields of robotics and artificial intelligence, with a particular focus on developing cooperation between autonomous agents in dynamic multiagent environments. A long-term grand challenge posed by RoboCup is the creation of a team of humanoid robots that can beat the best human soccer team by the year 2050. By concentrating on a small number of related, well-defined problems, many research groups both cooperate and compete with each other in pursuing the grand challenge.

RoboCup-2000 was held from August 27th to September 3rd, 2000, at the Melbourne Exhibition Center in Melbourne, Australia. In total, 83 teams, consisting of about 500 people, participated in RoboCup-2000. Over 5,000 spectators

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watched the events. RoboCup has been advancing steadily, both in terms of size and technological level since the first international event in 1997 which included 35 teams [16, 1, 4]. Specifically, RoboCup-2000 showed dramatic improvement in each of the existing robotic soccer leagues (legged, small-size, mid-size, and simulation), while introducing RoboCup Jr. competitions and RoboCup Rescue and Humanoid demonstration events.

In addition to the simulation-based and robotic events, the RoboCup-2000 workshop provided a forum for exchange of ideas and experiences among the different leagues. 20 oral presentations and 20 posters were presented, from which four papers were nominated for the RoboCup scientific and engineering challenge awards. These distinctions are given annually for the RoboCup-related research that shows the most potential to advance their respective fields.

This article summarizes the advances seen at RoboCup-2000. Sections 2–5 describe the 4 soccer-based competition leagues. Section 6 introduces RoboCup Rescue—a disaster rescue based research effort designed to transfer RoboCup-related research to humanitarian goals. RoboCup Jr., the RoboCup education effort aimed at school children is discussed in Section 7. Scheduled to debut as a full league in 2002, the RoboCup humanoid effort held a demonstration in Melbourne, which is described in Section 8. The article concludes with an overview of the RoboCup workshop in Section 9.

## 2 The Sony Legged Robot League

Since RoboCup-99, all participants in the Sony legged robot league have been using the quadruped robot platform [25] which is similar to the commercial entertainment robot AIBO ERS-110 (see Figure 1). The setup and the rules of the RoboCup-2000 legged competition were based on those of RoboCup-98 [6]. Each team has 3 robots, and the size of field is 1.8m x 2.8m. Objects such as the ball and goals are painted different colors. In addition, there are 6 poles with different colors at known locations for self-localization. As is the case in human soccer, there are penalties and regulations that govern the play. We introduced two changes from the previous year's rules in order to keep the game flowing and to encourage development of "team play" strategies. First, we introduced an obstruction rule, by which a robot that does not see the ball but is blocking other robots is removed from the play. Second, we modified the penalty area and applied the "two defender rule:" if there are two or more defenders in the penalty area, all but one is removed. As a result, the ball became stuck in the corner much less frequently. Moreover, the champion team, UNSW, implemented teammate recognition in order to avoid obstructing a teammate that was controlling the ball.

12 teams from 9 countries were selected to participate in the RoboCup 2000 Sony Legged Robot League: Laboratoire de Robotique de Paris (France), University of New South Wales (Australia), Carnegie Mellon University (USA), Osaka University (Japan), Humboldt University (Germany), University of Tokyo (Japan), University of Pennsylvania (USA), McGill University (Canada), Swe-

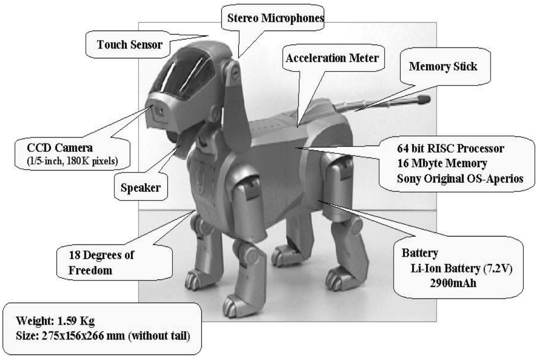


**Fig. 1.** The Legged Robot Platform.

den United team (Sweden), Melbourne United team (Australia), University of Rome (Italy), and University of Essex (UK). The first 9 teams above participated in the previous year's competition; the last 3 teams were new participants.

### 2.1 Championship Competition

For the competition, we divided the 12 teams into 4 groups of 3 teams each. After a round robin within in each group, the top 2 teams in each group proceeded to the final tournament. This year's champion is UNSW, followed by LRP in second place, and CMU in third place.

One significant improvement this year over past years was ball controlling technique. In RoboCup-99, the University of Tokyo team introduced the technique of propelling the ball with the robot's head, which can make the ball move a longer distance than can an ordinary kicking motion. This year almost all the teams implemented their own heading motion. Another impressive achievement for controlling the ball was introduced by UNSW. Their robots put the ball between their front legs, turned to change their heading while controlling the ball, and then kicked (pushed) the ball with both legs. This technique is very efficient for shooting the ball a long distance in a target direction.

### 2.2 RoboCup Challenge

In addition to the championship competition, every year we continue to hold the "RoboCup Challenge" as a technical routine competition. The challenge competition focuses on a particular technology more than the championship competition. This year we had 3 different technical routine challenges: (1) a striker challenge, (2) a collaboration challenge, and (3) an obstacle avoidance challenge.

The striker challenge was the simplest. The ball and one robot were placed in randomly selected positions (and orientation) on the field. The robot had to put the ball in the goal as quickly as possible. If it was unable to do so within 3 minutes, then the distance from the ball to the goal at the end of that period was measured. Note that the initial positions and orientation were selected after all the teams submitted their memory sticks with their developed software.

The collaboration challenge was defined in order to encourage the development of a passing behavior. There were two robots, one of which was put in the defensive half of the field (passer); the other was put in the offensive half (shooter). The passer and the shooter had to stay on their respective halves of the field, and the shooter had to kick the ball into the goal. The players were given 4 minutes to score a goal.

The obstacle avoidance challenge was also defined in order to encourage the development of team strategy as well as the ability to avoid a robot from the opposite team. One robot and the ball were placed on the field as in the striker challenge. In addition, two obstacles—a teammate robot with a red uniform and an opponent robot with a blue uniform—were placed at selected positions. The player had to score a goal without touching the obstacles. In both the collaboration and obstacle avoidance challenges, the time to score was recorded.

In order to complete the technical routine challenges, teams had to develop recognition algorithms for other robots, the half line, the ball, and the goals. Localization was also an important technology for the challenges.

In the striker challenge, 6 teams scored goals in an average time of 90 seconds. In the collaboration challenge, 6 goals were scored in an average of 100 sec. In the obstacle avoidance challenge, 4 teams scored in an average of 112 sec. All in all, about half of the participating teams were able to achieve the objectives of the 3 RoboCup Challenge tasks. UNSW won the challenge competition; Osaka University finished second; and CMU finished in third place.

| RANK | TEAM | SCORE |
|---|---|---|
| 1 | UNSW | 31 |
| 2 | OSAKA | 30 |
| 3 | CMU | 27 |
| 4 | SWEDEN | 27 |
| 5 | TOKYO | 24 |
| 6 | Melbourne | 16 |
| 7 | HUMBOLDT | 16 |
| 8 | ESSEX | 16 |
| 9 | McGill | 10 |
| 10 | ROME | 10 |
| 11 | UPENN | 10 |
| 12 | LRP | 10 |

**Fig. 2.** The result of the RoboCup Challenge.

# 3 F180: The Small-Size Robot League

Small-Size robot teams consist of up to 5 robots that can each fit into an area of 180 $cm^2$ (hence the alternative name Formula 180 or F180). The robots play on a green-carpeted table-tennis-sized field with sloping walls. The rules permit a camera to be perched above the field to be used with an off-field computer for a global vision system. This system is used to track the players, opponents and the ball. During a game the robots use wireless communication to receive tracking information from the off-field computer as well as commands or strategic information. No human intervention is allowed except for interpretation of the human referee's whistle.

The F180 games are exciting to watch as these robots can move *quickly*. The orange golf ball used as the soccer ball is propelled at speeds of over 3 m/s by ingenious kicking mechanisms. With the precise visual information from the global vision system the robots themselves can move at speeds over 1 m/s with smooth control. Nevertheless, robots moving at these speeds can and do have spectacular collisions. Intentional fouls can lead to robots being sent from the field under the shadow of a red card.

The need for speed and control has given the small-size league a reputation as the "engineering" league. Engineering disciplines including electro-mechanical design, applied control theory, power electronics, digital electronics and wireless communications have been the dominating factors in success in this league over recent years. Successful teams have typically demonstrated robot speed and powerful kicking rather than elegant ball control and sophisticated team strategies.

## 3.1 RoboCup 2000

Sixteen teams from nine different nations competed for the Small-Size Champion's trophy. The early rounds of the contest demonstrated the depth of the league, with some quality teams being eliminated during the round robin section. In particular, the MuCows from Melbourne University, Australia achieved remarkable performance in their first year in the contest but were unlucky to lose in a high class group. As well as solid all-around performance, the team from Melbourne showed their engineering skill with a high-bandwidth, low power communications system that was seemingly immune to the problems experienced by most competitors.

Three Small-Size teams chose not to use the global vision system; instead these teams relied on on-board vision capture and processing to sense the environment. These teams demonstrated that it is possible to build vision hardware suitable for real time processing within the severe size constraints of the F180 league. The ViperRoos from the University of Queensland, Australia had the distinction of becoming the first local vision team to beat a global vision team—the score was 2:0. However, none of the local vision teams were able to reach the finals.

The eight finalists all had excellent technical merit. Team Crimson from Korea has a custom video processing board that extracts the position of the players and the ball at the full NTSC video rate of 60 Hz. It does so without ever buffering the video in RAM, so that the position information is delayed by only 1/60th of a second. With such a small delay in vision processing combined with highly responsive robots, Team Crimson was capable of extremely fast and controlled motion. However, due to problems with communications (and some last minute code changes!) the team was knocked out in the quarter finals.

The French team from the Université Pierre et Marie Curie were the only team to score against the eventual champions, Big Red from Cornell University. The French curved path planning system allowed them to scoop the ball from in front of the opposition and make highly effective attacks on goal. They were unlucky to be knocked out by Cornell in their quarter final.

The first semi-final between FU-Fighters from the Freie Universitat of Berlin, Germany and the RoboRoos from the University of Queensland, Australia showed a contrast of styles. The RoboRoos, competing for the third consecutive year, had relied on smooth control and an adaptive team strategy to reach the finals, whereas the FU-Fighters used fast, aggressive trajectories with an extremely powerful kicker. The FU-Fighters showed clear dominance winning the match 3:0.

The second semi-final between Cornell and Lucky Star from Ngee Ann Polytechnic in Singapore was the closest match of the Small-size tournament. The match was 0:0 at full time, playing through a period of sudden death extra time to come down to a penalty shoot out that was decided at 4:3. Lucky Star combined novel electro-mechanical design with excellent control to achieve their result. Their robots had an extremely effective kicking mechanism that was integrated in a narrow body design. The narrow body enabled the robots to slip between defenders to get to the ball, despite the crowding of the field. Their vision and control was sufficiently good that they would reliably kick the ball despite the small kicking face of the robot. Lucky Star won third place in the contest.

The team from Cornell went on to win the final against the FU-Fighters convincingly. Figure 3 is a shot from the final game. This is the second consecutive year that Cornell has won the small-size championship and the second year that FU-Fighters have come second. While it might seem natural to attribute their achievements to novel electromechanical design such as FU-Fighter's powerful kicker or Cornell's dribbling device, it is also apparent that these robots are superbly controlled. As these control issues, along with the other fundamental engineering issues, are addressed on an even scale across the competition, other factors such as effective team strategies will come more into play.

## 4 F2000: The Middle-Size Robot League

The RoboCup F2000 League, commonly known also as middle-size robot league, poses a unique combination of research problems, which has drawn the attention of well over 30 research groups world-wide.

**Fig. 3.** The small-size league final game.

### 4.1 Environment and Robots

The playing environment is designed such that the perceptual and locomotion problems to be solved are reasonably simple, but still challenging enough to ignite interesting research. The field size is currently $9m \times 5m$. The goals have colored walls in the back and on the sides (yellow/blue). The field is surrounded by white walls (50cm height) that carry a few extra markings (squared black markers of 10cm size plus black-and-white logos of sponsors in large letters). A special corner design is used and marked with two green lines. The goal lines, goal area, center line and center circle are all marked with white lines. The ball is dark orange. Illumination of the field is constrained to be within 500 and 1500 lux. Matches are played with teams of four robots, including the goalie.

The robots must have a black body and carry color tags for team identification (light blue/magenta). Quite elaborate constraints exist for robot size, weight, and shape. Roughly, a robot body may be up to about 50cm in diameter and be up to 80cm in height; must weigh less than 80kg; and must have no concavities large enough to take up more than one-third of the ball's diameter. The robots must carry all sensors and actuators on-board; no global sensing system is allowed. Wireless communication is permitted both between robots and between robots and outside computers.

### 4.2 Research Challenges

The most notable difference from the F180 league is that global vision is not permitted. In a global camera view, all the robots and the ball move, while the goals, the walls and the markings of the field remain fixed. If the moving objects can be tracked sufficiently fast in the video stream, all the positions and orientations are known and a global world model is available. The situation is completely different in F2000, where the cameras on top of the robots are moving through the environment. All the usual directional cameras, and most omnidirectional cameras, can perceive only a small part of the environment. This greatly complicates tasks like finding the ball, self-localizing on the field, locating teammates and opponents, and creating and updating a world model. In addition, the vast majority of F2000 robots are completely autonomous, carrying all sensors and computational equipment onboard, which makes them much larger and heavier. Fast movements are much more difficult to control. These are two of the main reasons why F2000 robots play at much slower speeds than F180 robots.

The difficulties described above exert a strong force to new teams to think about robot design, and repeatedly new teams with new hardware designs have displayed stunning first-time appearances at RoboCup tournaments. This year we had another two examples: CMU Hammerheads from USA and GOLEM from Italy, each of which introduced a new mobile base into the middle-size league. The Hammerheads use a modified version of the commercially available Cye robot, a differential drive base with a trailer attached to it. The GOLEM robots feature a triangular omnidirectional drive design based on mechanum wheels, which provided for the best combination of maneuverability and speed the F2000 league has seen so far. The drive design of the GOLEM robots was complemented by the use of only a single sensor: an omnidirectional camera with a custom-made mirror design, which provided the robot with a complete view of the field from virtually every position. The clever combination of these two key design decisions allowed the GOLEM team to apply much simpler techniques for localization and world modeling as well as action selection, which significantly reduced development time.

### 4.3 RoboCup-2000 Tournament

Fifteen teams participated in the RoboCup-2000 middle-size league tournament. The rules for the middle-size robot league were only marginally changed from last year, which gave teams the opportunity to focus on software improvements rather than the design of new hardware. The play schedule was designed to give all teams ample opportunity to gain practical playing experience, with a total of 57 games. Each team was assigned to one of two groups, with 7 and 8 teams, respectively, for the qualification rounds. Each group played a single round robin schedule, such that each team played at least six or seven games. The four top teams in each group went to the playoff quarterfinals.

In this year's tournament, we had more exciting matches than ever, with quite a number of surprising performances. Most teams had previous tournament experience and showed significant progress over previous play levels. In addition, we had two remarkable newcomers this year, CMU Hammerheads from the United States and GOLEM from Italy, both of which made it to the quarterfinals, a remarkable success, especially for new teams. The other teams reaching the quarterfinals were last year's champion Sharif CE from Iran, RMIT United from Melbourne, Australia, the Osaka University Trackies from Japan, and the three German teams GMD Robots, Bonn, Agilo Robocuppers from Munich, and CS Freiburg. GOLEM, Sharif CE, Trackies, and CS Freiburg qualified for the semifinals. The semifinals and finals matches were the most exciting games in middle size league history, watched by a crowd of more than a thousand enthusiastic spectators. Both the third-place game and the final game took penalty shootouts to determine the winners. Last year's champion Sharif finished 3rd after tying the Trackies 1:1 at full-time and winning the penalty kicks 3:2. The final game between Freiburg and GOLEM was tied 3:3 at full-time. During the penalty shootout, Freiburg first scored three of five penalty kicks. Then, it was GOLEM's turn and they scored the first penalty kick. Excitement was at its peak when they missed the next two. Freiburg defended the next one as well and became the RoboCup-2000 middle size league champion.

### 4.4 Lessons Learned and Future Developments

When the newcomer team Sharif CE from Iran won last year, many observers attributed their superior performance largely to their new hardware design, which gave them more speed and more maneuverability than most other teams. With the GOLEM team from Italy, we had yet another team with a new mobile platform making it to the finals. Many AI people were concerned that the focus in F2000 would shift mainly to new mechanical designs and hardware work. However, this year CS Freiburg won the championship because of their superior software capabilities; except for slightly redesigned kickers, the hardware design has remained almost the same since the team started out in 1998. Many teams have much faster, more maneuverable robots than Freiburg.

The outcome of the last two tournament illustrate an old truth about mobile robots: *Better hardware may compensate for some software deficiencies, and better software may compensate for some hardware deficiencies.* Overall, there is still much work to do in *all* areas of cooperative, autonomous mobile robots. There is no precedence of any single field over another one; the only clearly identifiable precedence is that *robust and reliable* systems almost always win over less robust, less reliable teams. But robustness and reliability is something that one must achieve in all parts of a system.

After a year of keeping the rules virtually unchanged, it is now time to think about modifications that promote research particularly in two directions:

– *Making robots more robust and reliable.* Comparatively small changes in the environment often disturb the robots' performances significantly. Reducing the dependency on environmental color coding and to develop fast and robust algorithms for perceptual tasks like object detection, object localization, and object tracking is an essential goal for future research.
– *Enhancing playing skills.* Most robots push or kick the ball with a simple device; only few robots could demonstrate dribbling capabilities, such as taking the ball around an opponent in a controlled manner. Playing skills can be improved by more thorough application of learning techniques. In addition, we need to relax some of our constraints on robot's form and shape in order to promote the design of innovative ball manipulation devices.

Rule changes to foster research in these directions can be expected for future tournaments.

# 5 The Simulation League

The RoboCup 2000 competition was the most exciting and most interesting simulation competition so far. As in past years, the competition was run using the publicly available soccer server system [15]. 34 teams from 14 countries met in a round robin competition followed by a double elimination final series. While most of the teams had competed in previous competitions there were several notable new entries, including the eventual champions, FC Portugal who had an exciting 1:0 final with Karlsruhe Brainstormers. The high standard of the competition made for many exciting matches throughout the competition – nearly 25% of final-round games went into overtime, one eventually having to be decided by a coin toss after scoreless overtime lasted the length of two normal matches.

## 5.1 The RoboCup soccer server

The RoboCup soccer server provides a standard platform for research into multi-agent systems. The soccer server simulates the players and field for a 2D soccer match. 22 clients (11 for each team) connect to the server, each client controlling a single player. Every 100ms the Soccer Server accepts commands, via socket communication, from each client. The client sends low level commands (dash, turn or kick) to be executed (imperfectly) by the simulated player it is controlling. Clients can only communicate with each other using an unreliable, low bandwidth communication channel built into the soccer server. The soccer server simulates the (imperfect) sensing of the players, sending an abstracted (objects, e.g. players and ball, with direction, distance and relative velocity) interpretation to the clients every 150ms. The field of view of the clients is limited to only a part of the whole field. The Soccer Server enforces most of the basic rules of (human) soccer including off-sides, corner kicks and goal kicks and simulates some basic limitations on players such as maximum running speed, kicking power and stamina limitations.

An extra client on each team can connect as a "coach", who can see the whole field and send strategic information to clients when the play is stopped, for example for a free-kick.

The SoccerMonitor connects to the soccer server as another client and provides a 2D visualization of the game for a human audience (see Figure 4). Other clients can connect in the same way to do things like 3D visualization, automated commentary and statistical analysis.

Observers of the competition noted that, occasionally, watching RoboCup soccer games was like watching real soccer. This observation was likely based on the realism of the team level strategies, especially in the way the players moved the ball between themselves and, when not having the ball strategically positioned themselves to the teams advantage. The realism may also have been due to the flexibility the teams showed against unknown opponents and in novel situations.

**Fig. 4.** A screen-shot of the Soccer Server monitor augmented with FC Portugal's debugging tools.

### 5.2 Research Themes

RoboCup simulation requires the building of complete intelligent agents, i.e. agents must be capable of everything from handling uncertain sensors, through low level, real-time control to team coordination, in order to compete successfully. This is exciting because it shows RoboCup is exposing the strengths and weaknesses of our research and forcing us to address the weaknesses – in turn making that research stronger.

Many of the research challenges addressed by teams in 2000 came out of problems observed by teams from previous competitions. Two research themes were especially prominent, the first theme being learning and the second being multiagent coordination. Other research areas included improving situational awareness given incomplete and uncertain sensing and high level team specification by human designers.

The first research theme, especially common amongst the successful teams, was learning. Teams adapted techniques like simulated annealing, genetic programming or neural nets to the problem of creating very optimized low level skills such as dribbling (e.g. [20]). Experience has shown that while advanced skills were an essential component of a successful team, building such skills by hand is difficult and time consuming. The skills developed with learning techniques were in some cases superior to the hand developed skills of previous years. Hence, RoboCup has provided a useful, objective example of a case where learning can produce a better outcome than labor intensive programming.

Not all learning research was focused on low-level skills – several teams addressed the problem of how to learn high level strategies. RoboCup provides an interesting domain to investigate such issues because although there is a clearly defined objective function, i.e. win the game, the huge state space, unpredictable opponent, uncertainty, etc. make the problem very challenging. Most approaches learning at a high level layered the learning in some way (a successful approach in the 1999 competition), although the specifics of the learning algorithms varied greatly from neural networks to evolutionary algorithms.

The second major research theme was multiagent coordination. While in previous competitions, a highly skilled team might do reasonably well with "kiddie soccer" tactics, e.g. dribbling directly to goal, so many teams this year had high quality skills that more sophisticated team strategies were required to win games. Conversely, the high quality skills triggered more interest in team strategies because players had the ability to carry them out with some consistency. As well as the learning approach to developing high level strategies, a variety of human engineered approaches were used (e.g. [14]). A key to many of the approaches was the online coach. The coach was commonly used to analyze the opposition and determine appropriate changes to the team strategy [5]. Other teams developed tools or techniques aimed at empowering human designers to easily specify strategies. Yet, other teams relied on carefully engineered emergent team behavior (e.g. [19]) or dynamic team planning to achieve the desired team behavior.

### 5.3 RoboCup-2000

RoboCup simulation teams are increasingly complex pieces of software usually consisting of tens of thousands of lines of code with specialized components working together in real-time. Handling the complexity is forcing researchers to look critically at agent paradigms not only in terms of the resultant agent behavior but also at the ease with which very complex teams can be developed within that paradigm (and how that should be done).

However, the rapidly increasing complexity of RoboCup simulation agents should not deter new researchers from starting to work with RoboCup. An online team repository currently contains source code or binaries for 29 of the teams that competed in the 1999 World Cup plus many more from previous years. The repository allows new RoboCup participants to quickly get a team going. In fact a number of the top teams in 2000 were developed on top of the freely available code of the 1999 champions, CMUnited-99. The growing code base provides code for interaction with the soccer server, skills, strategies, debugging tools, etc. in a variety of programming languages and paradigms. A big effort has been made over the last few years to encourage teams to release source code or at least binaries of their teams.

The reigning champion team, CMUnited-99, was re-entered unchanged in the 2000 competition to assess the advances made during the year. In 2000 CMUnited-99 finished 4th. In 1999, CMUnited-99's aggregate goals for and against tally was 110-0, while in 2000 the tally was the far more competitive 25-7 (including a 13-0 win). Also interesting was that 4 of 6 of CMUnited-99's elimination-round games went into overtime (resulting in 3 wins and 1 loss). CMUnited-99's record in 2000 shows two things: (i) although they finished fourth several teams were nearly as good and, perhaps, unlucky to lose to them and (ii) the competition was extremely tight. It also indicates just how good CMUnited-99 were in 1999.

As well as the main competition, there were extensive evaluation sessions designed to compare the ability of teams to handle increased sensor and effector uncertainty. The sensor test was a repeat of the test from last year and involved changing the average magnitude of the error in the simulated visual information players received. The effector test was a surprise to the teams and involved changing the average magnitude of the difference between a command sent by a player and what was actually executed. The evaluation session provides a unique opportunity to test a wide variety of agent implementations under identical conditions. Extensive evaluation log-files, providing a large amount of high quality date, are available for analysis.

Despite the advances made in 2000, the RoboCup simulator is far from a solved problem. While high level learning has progressed significantly, learned high level strategies were generally inferior to hand-coded ones – a challenge for 2001 is to have learned strategies outperform hand-coded ones. Using RoboCup simulation as a platform for research into high level multiagent issues is only just starting to emerge, via, for example, use of the online coach. Additionally, as the standard of play gets higher there is both increased interest and use for opponent modeling techniques that can counter complex, previously unseen team strategies. The rapidly increasing complexity of RoboCup software challenges us to continue improving our methods for handling complexity. The advances made and the research areas opened up in 2000 bode well for yet another interesting, exciting competition in 2001.

## 6 RoboCup Rescue

The RoboCup-Rescue Project was newly launched by the RoboCup Federation in 1999. Its objective is as follows.

1. Development and application of advanced technologies of intelligent robotics and artificial intelligence for emergency response and disaster mitigation for the safer social system.
2. New practical problems with social importance are introduced as a challenge of robotics and AI indicating a valuable direction of research.
3. Proposal of future infrastructure systems based on advanced robotics and AI.
4. Acceleration of rescue research and development by the RoboCup competition mechanism.

A simulation project is running at present, and a robotics and infrastructure project will soon start.

In Melbourne, a simulator prototype targeting earthquake disaster was open to the public to start international cooperative research. A real rescue robot competition was proposed to start a new league in 2001.

### 6.1 Simulation Project

Distributed simulation technology combines the following heterogeneous systems to make a virtual disaster field. (i) *Disaster simulators* model the collapse of buildings, blockage of streets, spread of fire, traffic flow, and their mutual effects. (ii) *Autonomous agents* represent fire brigades, policemen, and rescue parties, all of which act autonomously in the virtual disaster. (iii) The *Simulation Kernel* manages state values and networking of/between the systems. (iv) The *Geographical Information System* gives spatial information to the whole system. (v) *Simulation Viewers* show 2D/3D image of simulation results in real time as shown in Fig. 5.

The RoboCup-Rescue simulation competition will start in 2001. The details are described in papers and a book [22, 9, 23, 7, 17, 21]. The simulator prototype can be downloaded from `http://robomec.cs.kobe-u.ac.jp/robocup-rescue/`.

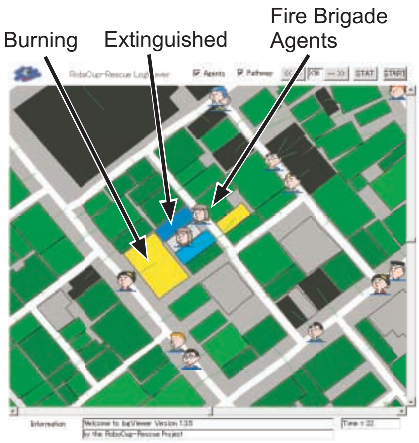


**Fig. 5.** 2D viewer image of RoboCup-Rescue prototype simulator.

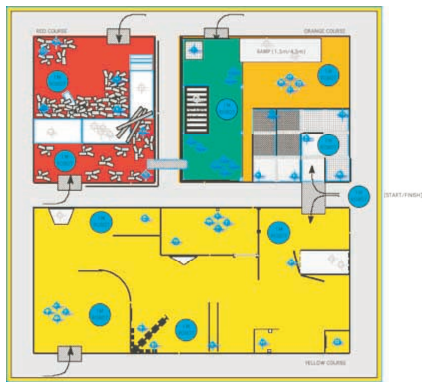

**Fig. 6.** AAAI USAR contest field.

### 6.2 AAAI/RoboCup Rescue Robot Competition

A rescue robot competition will start in 2001 in cooperation with AAAI. The target is search and rescue of confined people from collapsed buildings such as in earthquake disasters and explosion disasters. In Melbourne, Robin Murphy (USF) demonstrated 2 robots that are developed for real operations.

The large-scale arena of the AAAI Urban Search and Rescue (USAR) Contest (Fig. 6) will be used. It consists of three buildings simulating various situations. The easiest building has a flat floor with minimal debris, but the most difficult building includes a 3D maze structure consisting of stairs, debris, etc. with narrow spaces. The details are described on the AAAI USAR web page (`http://www.aic.nrl.navy.mil/~schultz/aaai2000/`).

More than other RoboCup competitions, the rules of the 2001 rescue competition will focus on direct technology transfer, specifically to real disaster problems on the basis of the 2000 AAAI USAR Contest. For example, practical semi-autonomy with human assistance and information collection for realistic operation are potential competition components.

## 7 RoboCup Junior

RoboCup Jr. is the educational branch of RoboCup, and it puts emphasis on teaching young people about research and technology by giving them hands-on experience. RoboCup Jr. development was initiated in 1997, and the first public show was at RoboCup'98 in Paris with a demonstration of LEGO Mindstorms robots playing soccer in a big LEGO stadium with rolling commercials, LEGO spectators making the wave, stadium lights, etc. [11] and with children playing with other LEGO robot models. In 1999, during RoboCup'99 in Stockholm, children were allowed to program their own LEGO Mindstorms robots in the morning, and then play tournaments in the afternoon [12]. The fast development of complex robot behaviors was achieved with the Interactive LEGO Football set-up based on a user-guided approach to behavior-based robotics. This activity was refined for RoboCup-Euro-2000 in Amsterdam [8], where 10 Dutch and 2 German school groups participated in a one-day tournament.

The RoboCup Jr. 2000 activity in Melbourne, in which a total of 40 groups of children participated, differed from the previous activities in several aspects: (1) children were both building and programming their robots, (2) the development took place during 6-8 weeks prior to the competition, (3) in most cases, the work was done as part of a teaching project in schools, (4) there was a robot sumo competition and a robot dance performance, in addition to the soccer competition.

During previous events, children had no opportunity to build the robots. But educational approaches such as constructionism [18, 10] suggest that the construction of an artifact is important in order to understand the artifact, so RoboCup Jr. 2000 allowed children to both build and program the robots. This endeavor was facilitated by the use of LEGO Mindstorms robots, partly because this tool allows for easy assembly of robots, and partly because most children are familiar with LEGO. The tasks were designed so that the simple sensors and actuators are sufficient, but a few children from the more advanced technical classes made their own sensors, and integrated them with the LEGO Mindstorms control unit.

There were three different events during RoboCup Jr. 2000, namely the Dance-Performance Event for students up to 12 years of age (Primary), the Converging Robot Race (Sumo) for students up to 14 years of age (Years 7 and 8), and RoboCup Jr 2000 Soccer for students of 14 to 18 years of age (Years 7 - 12). We put special emphasis on broadening RoboCup Jr. from being a purely competitive event to include the cooperative event of a robot dance/parade. In previous years, and during RoboCup Jr. 2000, we found the competitive robot soccer event to result in a gender bias towards boys. This bias is not surprising, since the robot soccer event promotes soccer, technology, vehicles, and competition, and we often find that boys are more enthusiastic about these subjects than girls. We did not perform any rigorous scientific gender studies, but our experience from many events gave a clear picture of a gender bias. We therefore introduced the dance/parade, in order to address other issues, such as cooperation, context construction, and performance. Indeed, more than 50% of the participants who signed up for the robot dance/performance event were girls.

Each participating team had 3 minutes for the robot dance/performance. The teams designed the robots; designed the environment in which the robots danced; programmed the robots to perform; and made a music cassette with the appropriate music for the performance. Many of the teams also designed their own clothes to match the robots and the environment, and many teams designed clothes for the robots. There was no limitation to the hardware (any robot can be used), but during RoboCup Jr. 2000, all participating teams chose to use LEGO Mindstorms. The performing robots included a Madonna look-alike, a disco-vampire, a dragon on the beach, and four feather-dressed dancers. Ten teams participated in the Dance/Performance Event, and prizes were given for best dressed robot, best programming, best choreography, most entertaining (best smile value), best team T-shirt design, best oral presentation by participants to judges, and creativity of entry.

The RoboCup Jr. soccer game had 20 participating teams. Each team built one or two robots (in all cases from LEGO Mindstorms) to play on a field of approximately 150cm $\times$ 90cm. The floor of the field is a gradient from black to white, which allows the robots to detect position along one of the axes by measuring reflection from the floor with a simple light sensor. The ball used in the finals was an electronic ball produced by EK Japan (see [12]). The ball emits infrared that can be detected with very simple, off the shelf LEGO sensors. Bellarine Secondary College won the final by drawing 3-3 and winning on golden-goal, after being down 3-0 at half time.

The success of the RoboCup Jr. 2000 event was to a large degree due to the involvement of very enthusiastic local teachers and toy/hardware providers, who promoted and designed the event in collaboration with the researchers. The local teachers were able to incorporate the RoboCup Jr. project in their curricula. Involvement of local teachers seems crucial for the success of such events. In the future, RoboCup Jr. will make an effort to promote national and local competitions, apart from the big events at the yearly RoboCup. Figure 7 shows images from this year's event.

## 8 Humanoid Robot Demonstration

The RoboCup humanoid league will start in 2002 towards the final goal of RoboCup, which is to beat the human World Cup soccer champion team with a team of eleven humanoid robots by 2050. This league will be much more challenging than the existing ones because the dynamic stability of robots walking and running will need to be handled.

The main steps of such development will be: (i) building an autonomous biped able to walk alone on the field; (ii) locomotion of this biped, including

**Fig. 7.** Images of the RoboCup Jr. events

straight-line movement, curved movement, and in-place turns; (iii) identification of the ball, the teammates, and the opponents; (iv) kicking, passing, shooting, intercepting, and throwing the ball; (v) acquisition of cooperative behavior (co-ordination of basic behaviors such as passing and shooting); and (vi) acquisition of team strategy.

Although items (iii)–(vi) are already addressed in the existing leagues, the humanoid league has its own challenges related to handling the ball with feet and hands.

At RoboCup-2000, the humanoid demonstration was held with four characteristic humanoids. Figure 8 shows these four humanoids, pictured from left to right. Mark-V, on the left is from Prof. Tomiyama's group at Aoyama Gauin Univirsity. Mark-V showed its ability to walk and kick a ball into a goal. Second from the left is PINO from the Kitano Symbio Project, Japan. PINO demonstrated walking and waving his hand to say "Good Bye!" Second from the right is Adam from LRP, France. Adam walked 100 cm in a straight line autonomously and was also controlled by an off-board computer. On the right is Jack Daniel from Western Australia University. Jack demonstrated a walking motion while suspended in the air.

These humanoids are still under development. At RoboCup-2001 we expect to see more humanoids with improved walking and running and also some new capabilities.

## 9 RoboCup Workshop and Challenge Awards

There is no doubt that RoboCup is an exciting event: the matches are thrilling to watch and the robots and programs are fun to design and build. Even so, RoboCup is fundamentally a *scientific* event. It provides a motivating and an easy to understand domain for serious multiagent research. Accordingly, the RoboCup Workshop, which is held each year in conjunction with the Robot Soccer World Cup, solicits the best work from participating researchers for presentation.

The RoboCup-2000 Workshop was held in Melbourne, adjacent to the exhibition hall where the competitions were staged. This year 20 papers were selected


**Fig. 8.** Four humanoids demonstrated at RoboCup-2000

for full presentation and an additional 20 were selected for poster presentation from over 60 submissions. Paper topics ranged from automated intelligent sportscaster agents to motion planners and vision systems. The Workshop was attended by over 200 international participants.

The number of high-quality submissions to the RoboCup Workshop continues to grow steadily. To highlight the importance of the scientific aspects of RoboCup, and to recognize the very best papers, the workshop organizers nominated four papers as challenge award finalists. The challenge awards are distinctions that are given annually to the RoboCup-related research that shows the most potential to advance their respective fields. The finalists were:

- *A localization method for a soccer robot using a vision-based omni directional sensor* by Carlos Marques and Pedro Lima.
- *Behavior classification with self-organizing maps* by Michael Wünstel, Daniel Polani, Thomas Uthmann and Jürgen Perl.
- *Communication and coordination among heterogeneous mid-size players: ART99* by Claudio Castelpietra, Luca Iocchi, Daniele Nardi, Maurizio Piaggio, Alessandro Scalso and Antonio Sgorbissa.
- *Adaptive path planner for highly dynamic environments* by Jacky Baltes and Nicholas Hildreth.

These presentations were evaluated by a panel of judges who attended the presentations based on the papers themselves, as well as the oral and poster presentations at the workshop. This year two awards were given: The scientific challenge award was given to Wünstel, *et al.* for their work on applying self-organizing maps to the task of classifying spatial agent behavior patterns; the engineering challenge award was given to Marques and Lima for their contribution to sensing and localization. All four finalist papers appear in this volume.

We expect that Workshop will continue to grow. In future years we may move to parallel tracks so that more presentations will be possible.

## 10 Conclusion

RoboCup-2000 showed many advances, both in the existing competition leagues and in the introduction of several new events. The participation and attendance were greater than ever, with about 500 participants and more than 5,000 spectators.

RoboCup-2001 is going to be held in the United States for the first time. It will run from August 2nd through August 10th, 2001 in Seattle co-located with the International Joint Conference of Artificial Intelligence (IJCAI-2001). RoboCup-2001 will include a 2-day research forum with presentations of technical papers, and all competition leagues: soccer simulation; RoboCup rescue simulation (for the first time); small-size robot (F180); middle-size robot (F2000); four-legged robot; and RoboCup rescue robot in conjunction with the AAAI robot competition (for the first time). It will also include a RoboCup Jr. symposium including 1 on 1 robot soccer and robot dancing competitions, and other educational events for middle-school and high-school children. Finally, RoboCup-2001 will include an exhibition of humanoid robots.

For more information, please visit: `http://www.robocup.org`.

## Appendix A: Sony Legged Robot League Results

This appendix includes all the results from the games in the Sony legged robot league. The tables show the preliminary round games, including numbers of wins, losses, and draws (W/L/D), and the rank of each team within each group. Figure 9 shows the results of the single-elimination championship tournament.

**Group A**

- A1: Osaka
- A2: Sweden
- A3: Tokyo

| | A1 | A2 | A3 | W/L/D | Rank |
|---|---|---|---|---|---|
| A1 | | 0–3 | 2–1 | 1/1/0 | 3 |
| A2 | 3–0 | | 2–4 | 1/1/0 | 2 |
| A3 | 4–2 | 1–2 | | 1/1/0 | 1 |

**Group B**

- B1: LRP
- B2: UPenn
- B3: Rome

| | B1 | B2 | B3 | W/L/D | Rank |
|---|---|---|---|---|---|
| B1 | | 2–1 | 4–0 | 2/0/0 | 1 |
| B2 | 1–2 | | 0–2 | 0/2/0 | 3 |
| B3 | 0–4 | 2–0 | | 1/1/0 | 2 |

**Group C**

- C1: UNSW
- C2: McGill
- C3: Essex

| | C1 | C2 | C3 | W/L/D | Rank |
|---|---|---|---|---|---|
| C1 | | 14–0 | 0–0 | 2/0/0 | 1 |
| C2 | 0–14 | | 0–0 | 1/1/0 | 2 |
| C3 | 0–0 | 0–0 | | 0/2/0 | 3 |

**Group D**

- D1: CMU
- D2: Humboldt
- D3: Melbourne

| | D1 | D2 | D3 | W/L/D | Rank |
|---|---|---|---|---|---|
| D1 | | 4–0 | 8–0 | 2/0/0 | 1 |
| D2 | 0–4 | | 1–0 | 1/1/0 | 2 |
| D3 | 0–8 | 0–1 | | 0/0/1 | 3 |

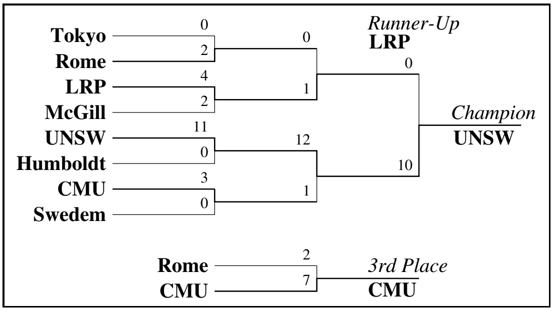


**Fig. 9.** The Sony legged robot league championship tournament.

## Appendix B: Small-Size Robot League Results

This appendix includes all the results from the games in the small-size robot league. The tables show the preliminary round games, including numbers of wins, losses, and draws (W/L/D), and the rank of each team within each group. Figure 10 shows the results of the single-elimination championship tournament.

**Group A**

- A1: Cornell Big Red
- A2: CFA UPMC
- A3: MU-Cows
- A4: 4 Stooges

| | A1 | A2 | A3 | A4 | W/L/D | Rank |
|---|---|---|---|---|---|---|
| A1 | | 1–1 | 7–0 | 40–0 | 2/0/1 | 1 |
| A2 | 1–1 | | 1–0 | 11–0 | 2/0/1 | 2 |
| A3 | 0–7 | 0–1 | | 14–0 | 1/2/0 | 3 |
| A4 | 0–40 | 0–11 | 0–14 | | 0/3/0 | 4 |

**Group B**

- B1: Fu Fighters
- B2: Rogi Team
- B3: TPOTS
- B4: CIIPS Glory

| | B1 | B2 | B3 | B4 | W/L/D | Rank |
|---|---|---|---|---|---|---|
| B1 | | 4–0 | 13–1 | 7–0 | 3/0/0 | 1 |
| B2 | 0–4 | | 2–0 | 10–0 | 2/1/0 | 2 |
| B3 | 1–13 | 0–2 | | 3–0 | 1/2/0 | 3 |
| B4 | 0–7 | 0–10 | 0–3 | | 0/0/3 | 4 |

**Group C**

- C1: LuckyStar II
- C2: Crimson
- C3: TUD
- C4: ViperRoos

| | C1 | C2 | C3 | C4 | W/L/D | Rank |
|---|---|---|---|---|---|---|
| C1 | | 24–0 | 66–0 | 7–0 | 3/0/0 | 1 |
| C2 | 0–24 | | 14–0 | 6–0 | 2/1/0 | 2 |
| C3 | 0–66 | 0–14 | | 0–2 | 0/3/0 | 4 |
| C4 | 0–7 | 0–6 | 2–0 | | 1/2/0 | 3 |

**Group D**

- D1: RoboRoos
- D2: Field Rangers
- D3: All Botz
- D4: Yale Frobocup

| | D1 | D2 | D3 | D4 | W/L/D | Rank |
|---|---|---|---|---|---|---|
| D1 | | 0–1 | 14–1 | 22–0 | 2/1/0 | 2 |
| D2 | 1–0 | | 6–0 | 8–1 | 3/0/0 | 1 |
| D3 | 1–14 | 0–6 | | 1–0 | 1/2/0 | 3 |
| D4 | 0–22 | 8–1 | 0–1 | | 0/3/0 | 4 |

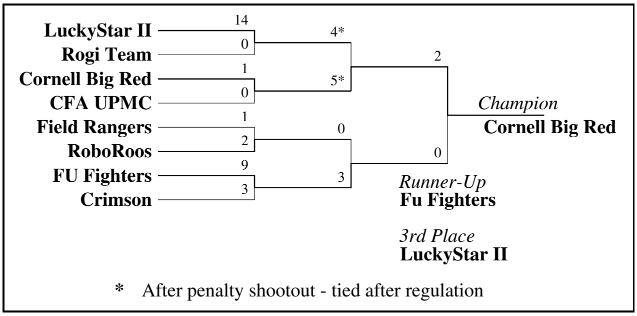


**Fig. 10.** The small-size robot league championship tournament.

## Appendix C: Middle-Size Robot League Results

This appendix includes all the results from the games in the middle-size robot league. The tables show the preliminary round games, including numbers of wins, losses, and draws (W/L/D), and the rank of each team within each group. Figure 11 shows the results of the single-elimination championship tournament.

**Group A**

- A1: CS Freiburg
- A2: Vanquish
- A3: CoPS Stuttgart
- A4: RMITUnited
- A5: KIRC
- A6: NAIST 2000
- A7: Sharif CE
- A8: Golem Team

| | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | W/L/D | Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| A1 | | 8–0 | 3–1 | 3–0 | 4–0 | 9–1 | 5–1 | 1–2 | 6/1/0 | 1 |
| A2 | 0–8 | | 0–1 | 0–8 | 2–2 | 0–1 | 0–4 | 0–8 | 0/6/1 | 8 |
| A3 | 1–3 | 1–0 | | 0–2 | 2–0 | 2–0 | 0–2 | 1–6 | 3/4/0 | 5 |
| A4 | 0–3 | 8–0 | 2–0 | | 8–1 | 7–0 | 1–3 | 3–5 | 4/3/0 | 4 |
| A5 | 0–4 | 2–2 | 0–2 | 1–8 | | 0–2 | 0–5 | 1–5 | 0/6/1 | 7 |
| A6 | 1–9 | 1–0 | 0–2 | 0–7 | 2–0 | | 0–9 | 0–6 | 2/5/0 | 6 |
| A7 | 1–5 | 4–0 | 2–0 | 3–1 | 5–0 | 9–0 | | 4–1 | 6/1/0 | 3 |
| A8 | 2–1 | 8–0 | 6–1 | 5–3 | 5–1 | 6–0 | 1–4 | | 6/1/0 | 2 |

**Group B**

- B1: Agilo Robocuppers
- B2: GMD-Robots
- B3: CMU Hammerheads
- B4: Vanquish
- B5: Win KIT
- B6: ART 2000
- B7: Trackies

| | B1 | B2 | B3 | B4 | B5 | B6 | B7 | W/L/D | Rank |
|---|---|---|---|---|---|---|---|---|---|
| B1 | | 0–2 | 2–0 | 3–1 | 3–0 | 1–0 | 0–4 | 4/2/0 | 3 |
| B2 | 2–0 | | 1–1 | 2–0 | 3–1 | 1–0 | 0–7 | 4/1/1 | 2 |
| B3 | 0–2 | 1–1 | | 0–2 | 3–0 | 4–1 | 1–4 | 2/3/1 | 4 |
| B4 | 1–3 | 0–2 | 2–0 | | 4–1 | 0–0 | 0–5 | 2/3/1 | 5 |
| B5 | 0–3 | 1–3 | 0–3 | 1–4 | | 0–0 | 0–7 | 0/5/1 | 7 |
| B6 | 0–1 | 0–1 | 1–4 | 0–0 | 0–0 | | 1–8 | 0/4/2 | 6 |
| B7 | 4–0 | 7–0 | 4–1 | 5–0 | 7–0 | 8–1 | | 6/0/0 | 1 |

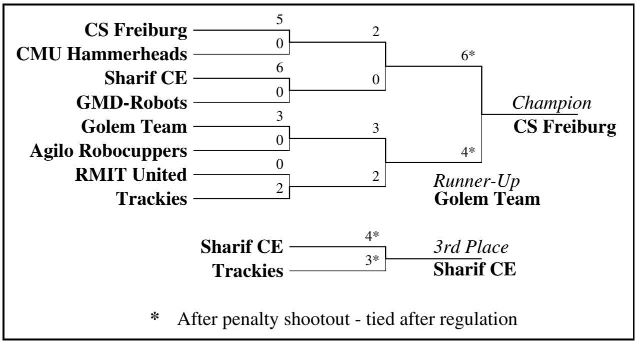


**Fig. 11.** The middle-size robot league championship tournament.

## Appendix D: Simulation League Results

This appendix includes all the results from the games in the simulator league. The tables show the preliminary round games, including numbers of wins, losses, and draws (W/L/D), and the rank of each team within each group. Figure 12 shows the results of the double-elimination championship tournament.

**Group A**

- A1: ATT-CMUnited-2000
- A2: Open Zeng
- A3: A-Team
- A4: Virtual Werder

| | A1 | A2 | A3 | A4 | W/L/D | Rank |
|---|---|---|---|---|---|---|
| A1 | | 1–0 | 13–0 | 6–0 | 3/0/0 | 1 |
| A2 | 0–1 | | 9–0 | 4–2 | 2/1/0 | 2 |
| A3 | 0–13 | 0–9 | | 0–16 | 0/3/0 | 4 |
| A4 | 0–6 | 2–4 | 16–0 | | 1/2/0 | 3 |

**Group B**

- B1: CMUnited-99
- B2: Gemini
- B3: Sharif II
- B4: SBC

| | B1 | B2 | B3 | B4 | W/L/D | Rank |
|---|---|---|---|---|---|---|
| B1 | | 2–0 | 8–0 | 4–0 | 3/0/0 | 1 |
| B2 | 0–2 | | 4–0 | 1–0 | 2/1/0 | 2 |
| B3 | 0–8 | 0–4 | | 1–0 | 1/2/0 | 3 |
| B4 | 0–4 | 0–1 | 0–1 | | 0/3/0 | 4 |

**Group C**

- C1: Magma Freiburg
- C2: TakAI
- C3: Gnez
- C4: Paso Team

| | C1 | C2 | C3 | C4 | W/L/D | Rank |
|---|---|---|---|---|---|---|
| C1 | | 3–0 | 14–0 | 25–0 | 3/0/0 | 1 |
| C2 | 0–3 | | 4–0 | 21–0 | 2/1/0 | 2 |
| C3 | 0–14 | 0–4 | | 5–0 | 1/2/0 | 3 |
| C4 | 0–25 | 0–21 | 0–5 | | 0/3/0 | 4 |

**Group D**

- D1: Essex
- D2: HC-IV
- D3: Sharif Arvand
- D4: Spatial Timer
- D5: KU-Yam

| | D1 | D2 | D3 | D4 | D5 | W/L/D | Rank |
|---|---|---|---|---|---|---|---|
| D1 | | 10–0 | 0–0 | 7–0 | 16–0 | 3/0/1 | 2 |
| D2 | 0–10 | | 0–18 | 0–11 | 1–1 | 0/3/1 | 5 |
| D3 | 0–0 | 18–0 | | 3–0 | 18–0 | 3/0/1 | 1 |
| D4 | 0–7 | 11–0 | 0–3 | | 3–0 | 2/2/0 | 3 |
| D5 | 0–16 | 1–1 | 0–18 | 0–3 | | 0/3/1 | 4 |

**Group E**

- E1: FC Portugal
- E2: Robolog
- E3: Zeng00
- E4: Oulu2000

| | E1 | E2 | E3 | E4 | W/L/D | Rank |
|---|---|---|---|---|---|---|
| E1 | | 20–0 | 18–0 | 33–0 | 3/0/0 | 1 |
| E2 | 0–20 | | 0–0 | 39–0 | 1/1/1 | 2 |
| E3 | 0–18 | 0–0 | | 21–0 | 1/1/1 | 3 |
| E4 | 0–33 | 0–39 | 0–21 | | 0/3/0 | 4 |

**Group F**

- F1: Karlsruhe
- F2: Mainz
- F3: Kakitsubata
- F4: Wright Eagle

| | F1 | F2 | F3 | F4 | W/L/D | Rank |
|---|---|---|---|---|---|---|
| F1 | | 10–0 | 18–0 | 1–0 | 3/0/0 | 1 |
| F2 | 0–10 | | 7–0 | 0–7 | 1/2/0 | 3 |
| F3 | 0–18 | 0–7 | | 0–8 | 0/3/0 | 4 |
| F4 | 0–1 | 7–0 | 8–0 | | 2/1/0 | 2 |

**Group G**

- G1: YowAI
- G2: Cyberoos 2000
- G3: GSP
- G4: Lucky Lubeck
- G5: Polytech 100

| | G1 | G2 | G3 | G4 | G5 | W/L/D | Rank |
|---|---|---|---|---|---|---|---|
| G1 | | 4–0 | 28–0 | 18–0 | 6–0 | 4/0/0 | 1 |
| G2 | 0–4 | | 27–0 | 13–0 | 3–0 | 3/1/0 | 2 |
| G3 | 0–28 | 0–27 | | 0–12 | 0–16 | 0/4/0 | 5 |
| G4 | 0–18 | 0–13 | 12–0 | | 1–0 | 2/2/0 | 3 |
| G5 | 0–6 | 0–3 | 16–0 | 0–1 | | 1/3/0 | 4 |

**Group H**

- H1: 11 Monkeys
- H2: AT Humboldt 2000
- H3: Harmony
- H4: PSI

| | H1 | H2 | H3 | H4 | W/L/D | Rank |
|---|---|---|---|---|---|---|
| H1 | | 4–0 | 13–0 | 10–0 | 3/0/0 | 1 |
| H2 | 0–4 | | 9–0 | 5–0 | 2/1/0 | 2 |
| H3 | 0–13 | 0–9 | | 0–3 | 0/3/0 | 4 |
| H4 | 0–10 | 0–5 | 3–0 | | 1/2/0 | 3 |

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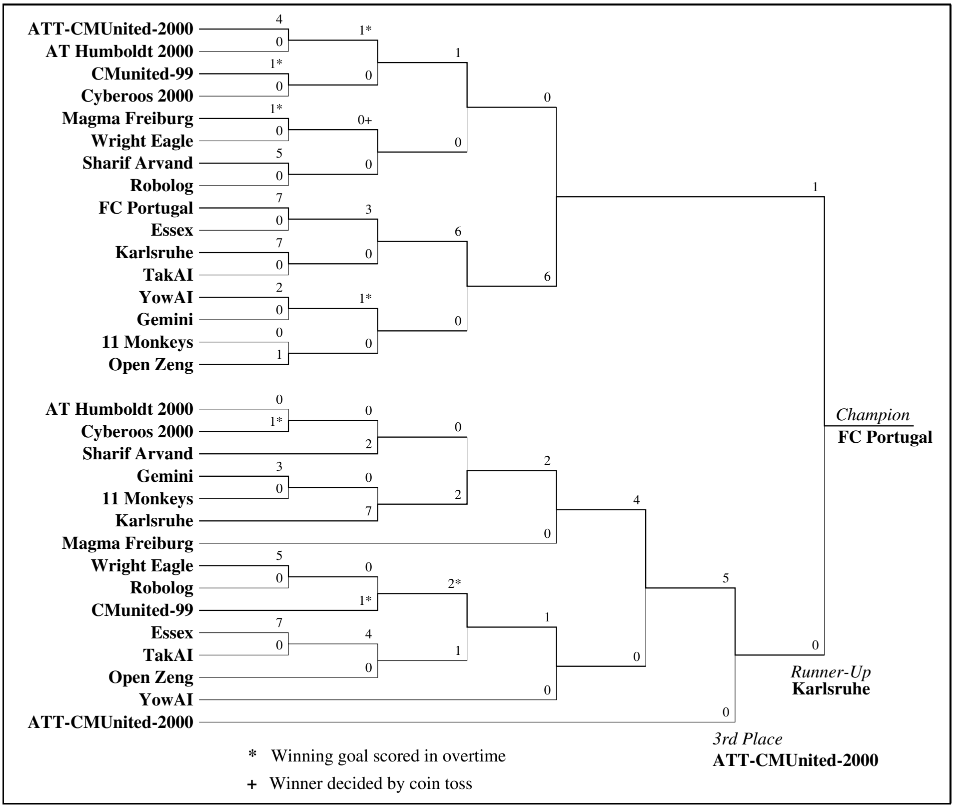


**Fig. 12.** The simulation league championship tournament.

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