RoboCup: Robot World Cup

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Robot World Cup

In an attempt to promote artificial intelligence (AI) and robotics research, RoboCup (Robot World Cup) was organized to provide a common environment for the evaluation of various theories, algorithms, and agent architectures [2]. In order for the robot (physical robot and software agent) to play a soccer game reasonably well, a wide range of technologies need to be integrated. The range of technologies spans both AI and robotics research, including the design of autonomous agents, multi-agent collaboration, strategy acquisition, real-time reasoning and planning, intelligent robotics, and sensor-fusion, to name a few. The first RoboCup, RoboCup-97, was held during the International Joint Conference on Artificial Intelligence (IJCAI-97) at Nagoya, Japan. A series of competitions are planned for the future, such as a Formula One Championship. Currently, RoboCup consists of three competition categories:

Real Robot League:
: In this league, physical robots are used to play soccer games.
In RoboCup-97, there were two categories: small-size league and middle size league.

Small-Size League:
: The small-size league consisted of five robots per team, played on a field the size of a ping-pong table. Each robot was about 15-18cm in diameter, with a cross-sectional area of less than 180cm^2. An orange golf ball was used as the ``soccer ball."

Middle-Size League:
: The middle size league used five robots per team. Each robot was within 50cm in diameter, and 2,000cm^2 in cross-sectional area. A FIFA Size 4 Futsal ball was used. The teams played on a field the size of 9 ping-pong tables (3 by 3).

Software Robot League:
: Using software agents, the soccer game was played on an official soccer server over the network. Each player is connected via UDP/IP and only receives ego-centric noisy visual information.

Expert Robot Competition:
: Competition of robots which have special skills, but are not able to play a game of soccer. In other words, these robots have mastery of a specific skill such as shooting, intercepting, etc.

Although RoboCup's primary objective is a soccer game with real robots, RoboCup also offers an opportunity for research on the software aspects of AI and robotics. The software robot league, also called the simulator league, enables more researchers to take part in this event. It also promotes research on network-based multi-agent interactions, computer graphics, and physically realistic animations. In addition, we intend to create an award for expert robots which demonstrate a high-level of competence for a specific task, such as shooting, intercepting, etc.

Why RoboCup?

It is our intention to use RoboCup as a vehicle to revitalize AI research by offering a publicly appealing, yet difficult, challenge. One of the effective ways to promote engineering research, apart from specific application development, is to set a significant long term goal. When the accomplishment of such a goal has significant social impact, it is called a grand challenge project. Building a robot to play soccer games does not generate significant social and economic impact in itself, but the accomplishment will certainly be considered as a major achievement in the field. We call this kind of project a landmark project. RoboCup is a landmark project as well as a standard problem.

A successful landmark project claims to accomplish broadly appealing goals. The most successful example is the Apollo space program. In the case of the Apollo project, the U.S. accomplished its goal of ``landing a man on the moon and returning him safely to earth'' [1]. The accomplishment of the goal itself marks the history of mankind. Although the direct economic impact of having someone landed on the moon is small, the technologies developed to achieve this goal were significant in becoming the foundation to American industries. The important issue for a landmark project is to have goals high enough so that a series of technical breakthroughs are necessary to accomplish the task; moreover, the goal needs to be widely appealing and exciting. In addition, the set of technologies necessary to accomplish the goal must be the technologies which can form the foundation for industries in the next generation.

In the case of RoboCup, the ultimate goal is to ``develop a robot soccer team which beats the Brazillian World Cup team.'' A more modest goal is ``to develop a robot soccer team which play like human players.'' Needless to say, the accomplishment of the ultimate goal will take decades, if not centuries. With current technologies, it is not possible to accomplish this goal in the near future. However, this goal may inspire a series of well-directed subgoals. The first subgoal to be accomplished in RoboCup is to build real and software robot soccer teams which can play reasonably well with modified rules. To accomplish this goal will require technologies which will have a broad impact on industries.

One other aspect of RoboCup is the view that RoboCup is a standard problem where various theories, algorithms, and architectures can be evaluated. Computer chess is a typical example of a standard problem. Various search algorithms were evaluated and developed under this context. With the recent victory of Deep Blue over Kasparov, a human grand master, using official rules, the computer chess challenge is near its close. One of the major reasons for the success of computer chess as a standard problem is that the evaluation of the progress was clearly defined. However, as the challenge of computer chess is overcome, we need a new challenge. The challenge needs to foster a set of technologies for industries of the next generation. We believe RoboCup will fulfill such a demand. Table 1 illustrates several characteristic differences of the challenge of computer chess and that of RoboCup.

	Chess	**RoboCup**
Environment	Static	Dynamic
State Change	Turn taking	Real time
Information accessibility	Complete	Incomplete
Sensor Readings	Symbolic	Non-symbolic
Control	Central	Distributed

Table 1: Comparison of Chess and RoboCup

RoboCup was designed to meet the need of handling real world complexities, though in a limited world, while maintaining a reasonable problem size and research cost. RoboCup offers an integrated research problem covering broad areas in the fields of AI and robotics. Such areas include: real-time sensor fusion, reactive behavior, strategy acquisition, learning, real-time planning, multi-agent systems, context recognition, vision, strategic decision-making, motor control, intelligent robot control, and many more.

RoboCup-97 Nagoya

The First Robot World Cup Soccer Games and Conferences (RoboCup-97) was held during IJCAI-97 Nagoya, August 23-29, 1997. Over 40 teams throughout the world participated in the competition: Thirty-two teams (Europe: 8, North America: 8, Australia: 2, Japan: 14) in the simulator league; four teams (Carnegie Mellon University (USA), Paris-VI (France), University of Girona (Spain), and Nara Advanced Institute of Science and Technology (Japan)) in the small-size robot league; and five teams (ISI/USC (USA), Osaka University (Japan), Ullanta Performance Robotics (USA), RMIT (Australia), and Uttori United - A joint team of Riken, Toyo University, and Utsunomiya University (Japan)) participated in middle size league. Prior to the competition, a two-day technical workshop was held with the presentation of 30 technical papers and a poster session for all participating teams.

The simulation league used a round-robin system to select the top 16 teams. Eight groups of four teams were created, and the top two teams from each group advanced to the final games starting from hexa-finals. The champion of the simulation league was AT-Humboldt from the Humboldt University, Germany, who beat the AndHill from the Tokyo Institute of Technology in the final round. Third place goes to ISI Synthetics (ISIS) from ISI/USC which defeated CMUnited from Carnegie Mellon in the third place play-off.

AT-Humboldt uses agent-oriented programming and case-based reasoning, and AndHill uses reinforcement learning to train their synthetic soccer players. Despite general expectations that a hard-coded non-AI program may have advantages in the first few years of competition, we have already witnessed that for such a complex domain, AI-based systems exhibit a significant advantage over non-AI hard-coded programs. While more detailed investigation of what was actually happening in the competition is necessary to draw any conclusions, the fact that most top teams were serious AI-based systems was very encouraging to the AI community.

The small-size league World Champion was awarded to CMUnited from Carnegie Mellon University which defeated the Nara Advanced Institute of Science and Technology, Japan (score: 3-0) in the finals.

The Middle-size league final resulted in a draw (0-0) between the Dreamteam of ISI/USC and the Trackies of Osaka University. Their score in the preliminary round was also a draw of 2-2. The committee decided to award both teams the World Championship.

Aside from the winner of each league, RoboCup awards a Scientific Challenge Award and an Engineering Challenge Award to the team which met a major challenge with some success. This award was established to foster challenging scientific and engineering research in RoboCup. In general, the strategy for winning the competition is to use conventional and reliable technologies well-tuned for a specific domain. Since the domain of RoboCup is challenging, any successful team necessarily introduces some challenging technologies. However, these awards are given for truly high-risk and high impact designs.

In RoboCup-97, The Scientific Challenge Award was given to Sean Luke of University of Maryland for demonstrating the utility of evolutionary programming by evolving soccer teams. Sean Luke used Genetic Programming to evolve soccer players by running the simulator on massively parallel machines for a few months. The evolved team beat some human hand-coded teams and survived the round robin tournament to advance to the hexa-finals.

Two engineering challenge awards were awarded to UttoriUnited and RMIT, for designing novel omni-directional driving mechanisms. These teams designed new robot driving mechanisms which use special wheels (Uttori) and balls (RMIT) to enable the robots to move to any direction without rotation. Such mechanisms significantly improve the robots' maneuvrability, and their potential impact is far reaching.

During RoboCup-97, over 5,000 general spectators watched the games, and the event was covered by over 70 world media, such as CNN, ABC, NHK, BBC, Sky Channels, Le Monde, Der Spigel, Le Figaro, and Business Week.

Future RoboCup Games and Conferences

The future RoboCup schedule is shown in Table 2.

RoboCup-98 Paris	July 2-9	with ICMAS and the World Cup
RoboCup-98 Victoria	Oct	with IROS-98
RoboCup Pacific Rim 98 at Singapore	Nov.	with PRICAI-98
RoboCup-99 Stockholm	July	with IJCAI-99
RoboCup-2000	to be announced	
RoboCup-2001 Seattle	August	with IJCAI-2001 (tentative)
RoboCup-2002 Japan	TBA	with World Cup 2002

Table 2: RoboCup Schedule

A few new categories will be introduced as the technology develops. In RoboCup-98 Paris, exhibition games will be held using legged robot teams. Each robot has four legs and a head. It is expected that a robot have about 15 degree of freedom. It is a challenging task to control such a robot in real-time to play a soccer game.

Also, a new Full-Set Small Size League will use 11 players per a team, and will be played on a middle size field. Increase in the number of robots will drastically increase the complexity of the problem.

In the future, we are planning on organizing a humanoid robot league. It will be subdivided into two categories: full autonomous league and teleoperation league. With the emergence of bi-pedal humanoid robots, such as the Honda Humanoid Robot, this is no longer just a science fiction dream. It is certainly within the scope of serious researchers' goals. Such a humanoid robot is expected to be almost the same size as a human being and they are expected to play on real soccer studiums someday in the future.

RoboCup has a dream and challenge. It is one of the fastest growing areas of AI and robotics research today. The community is expanding, and there is extensive sharing of knowledge and resources for the common dream. On behalf of the RoboCup community, the authors welcome and invite the active participation of readers of the ACM Crossroads student magazine.

References

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