What's Hot at RoboCup (Extended Abstract)

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RoboCup 2016 in Leipzig, Germany will be the 20th annual international RoboCup competitions and symposium. Since the inaugural event at IJCAI 1997 during which three soccer competitions were held in half of a hotel ballroom, RoboCup has grown to include various competitions beyond soccer, and routinely fills a whole convention center. Accompanying the competition each year there has been a symposium with proceedings published in book format that include refereed technical contributions related to RoboCup and often, invited papers from that year's champion teams.

Full information about the history, mission, and organization of RoboCup is available at www.robocup.org. This paper does not recap these items. Rather, in the spirit of the AAAI "What's Hot" track, the aim is to give an overview of the latest and most innovative developments, as well as highlighting some of the current and future challenges upon which today's RoboCup participants are focused.

By far the best way to experience what's hot at RoboCup is to attend in person. With routinely more than 2,000 registered participants competing in more than ten different leagues and subleagues, each with its own rules and technical challenges, the four days of competition and subsequent symposium leave hardly enough time to fully appreciate all of the details. The reader with the time and resources is encouraged to stop reading here, and instead plan to attend (or better yet, participate in!) an upcoming RoboCup competition. One would expect to see:

- Hundreds of fully autonomous robots all simultaneously executing complex sensing, decision-making, and acting;
- Fast-moving, wheeled robots passing a ball with amazing precision;
- Novel, award-winning, humanoid open platforms that can walk on artificial grass and stand up by themselves;
- Innovative service robots communicating through speech and manipulating objects in unstructured environments;
- Highly mobile rescue robots navigating over complex terrains in a NIST standard arena;
- Complex, learned individual and multi-robot behaviors;
- Many other technical AI and robotics achievements.

For those who are not so fortunate to get firsthand experience, the remainder of this extended abstract, and accompanying talk at AAAI, aim to serve as a pale substitute. There are far too many RoboCup-related developments to cover all of them in detail. What follows is a sampling.

Color-free Environments: SPL, HL. RoboCup includes two soccer leagues that use humanoid robots. In the Standard Platform League (SPL), teams use identical robot hardware - currently the Aldebaran Nao robot. In the Humanoid League (HL), teams build their own robots. Traditionally, both leagues have used color-coded environments in order to simplify the vision problem. Goals have been blue on one side of the field and yellow on the other, and the ball has been orange. Both leagues have now moved to fully symmetric fields with two white goals. Participating teams have risen to the challenge by developing new, more robust vision and cooperative localization algorithms.

Audio Communication: SPL. A perennial challenge at RoboCup is that hundreds of robots in the same room are all communicating over wifi simultaneously. Inevitably chaos ensues — or at least communication flakiness. One SPL team this year demonstrated audio-based communication using high-pitched frequencies. The league is considering requiring such communication in the future.

Push Recovery and High Jumping: HL. Robust, highly dynamic walking is a major focus of the HL. This year, robots were challenged to exhibit push recovery and were tested on a high jump challenge.

Human Robot Interaction: @Home. One of the beyond-soccer leagues at RoboCup, RoboCup@Home, deals with service robots in domestic environments. The robots exhibit impressive human-aware navigation, behavior recognition, gesture recognition, and speech-based interaction. Current participants are developing intuitive user interfaces using mobile phones, touch pads, or other such devices in order to allow naive users to operate a robot without speech.

Manipulation: @Home, Logistics, @Work. Two other beyond-soccer leagues are RoboCup@Work and the Logistics League. Both are joining @Home in encouraging research on manipulation. The 2015 RoboCup@Work competition featured a pick-and-place scenario.

Passing: SSL, 2DSIM, MSL, 3DSIM. Some soccer leagues have exhibited fast, robust passing for years. In particular, the Small Size League (SSL), which features very fast, small robots controlled remotely and perceived by an overhead camera, has exhibited impressive, precise passing, as has the 2D simulation league (2DSIM), which features

simulated agents executing abstract commands. However, most of the other leagues have tended to be more focused on low-level individual skills such as walking, kicking, and dribbling. Two such leagues have taken concrete steps to encourage passing. The Middle Size League (MSL), which features fast-moving, large wheeled robots that play with a regulation soccer ball, saw more than half of the goals scored during the 2015 competition preceded by at least one in-game pass. Similarly the 3D Simulation League (3DSIM), which features simulated humanoid robots in an ODE-based physical simulator had in prior years been decided by the fastest, most robust walking and dribbling skills. In 2015, teams demonstrated the ability to kick the ball to precise locations, which led to much more passing during game play.

Ad Hoc Teamwork: SPL, 3DSIM, 2DSIM, SSL. Along a similar theme of teamwork, recent years have seen interesting experiments on ad hoc teamwork. Traditional RoboCup teams have been programmed by the same group, and thus highly coordinated by design. In contrast, ad hoc teamwork studies the ability of agents to cooperate without pre-coordination. To this end, SPL, 3DSIM, 2DSIM, and SSL have all run games in which teams are composed of players from different teams that need to figure out, on the fly, how to work as a team.

Competition Formats: 2DSIM. One of the advantages of the simulation leagues is their ability to run the same matchup thousands of times to establish the statistical significance of results. This in contrast to the robot leagues, which necessarily live with the same sort of stochasticity that arises in human sports competitions. Leveraging this replicability, the 2DSIM league is evaluating different tournament structures to minimize non-transitivity and inherent stochasticity of team performance.

Automatic Refereeing: SSL. Most RoboCup leagues require human oversight during games to enforce the rules. The SSL is challenging teams to develop an automatic referee that takes the same overhead video feed as is provided to the players and can determine when goals are scored and which team touched the ball last when the ball goes out of bounds. The robots themselves may then place the ball for a free kick as instructed by the automatic referee.

More Realistic Environments: MSL, HL, Rescue, @Home. RoboCup leagues always strive to strike a balance between playability and realism. Many leagues are now striving to push the boundaries of realism, and hoping that playability will follow as teams step up to the technical challenges involved. For example, the MSL and HL are both moving towards playing on artificial grass instead of a perfectly flat carpet. The RoboCup Rescue league, which features robots searching for victims in simulated disaster areas, is adding more confined spaces to the arena, thus forcing teams to consider smaller robots (including ones that are 3D printed and customized for the intended application). @Home has always conducted tests in public places where the environment cannot be controlled, such as supermarkets, restaurants, and toy stores. The league is now increasing the number of such "in the wild" tests. For example, in 2016 robots will need to guide people through crowded parts of the RoboCup venue and/or do manipulation tests in places with uncontrolled lighting, including direct sunlight.

ROS-based Simulation: 3DSIM, Virtual Rescue. The RoboCup simulation leagues have typically used custom, community-maintained simulators. While doing so has given the community full control over features, it has also been a burden on the community, and created a barrier to entry for new teams. In response, both 3DSIM and the Virtual Robot Rescue league (one of the two rescue simulation leagues) are developing ROS-based simulation environments in the Gazebo simulation environment. One goal of such a move is to encourage research groups with experience in Gazebo, such as all the teams that participated in the recent DARPA Robotics Challenge, to enter RoboCup.

Increased Complexity: Logistics. The logistics league, which features robots managing a simulated manufacturing plant, is increasing the number of product variants from 3 to almost 250. This change will dramatically increase the multi-robot planning and reasoning complexity. Since orders are dynamically sent to the robots at run-time, planning has to happen in a short time and with flexible execution.

11 vs. 11 Robot Games: SSL. The real-robot soccer leagues have typically been limited to at most 5 robots per team. The SSL has been the first to impressively demonstrate games with teams of 11 robots on each team.

Benchmarking: @Home. Whereas soccer games are easily evaluated based on number of goals scored, the beyond-soccer leagues face a less well-defined evaluation challenge. @Home is engaged in an ongoing effort to set the worldwide standard for benchmarking service robot capabilities.

While this sampling of developments is presented from the perspective of the RoboCup leagues, it is important to keep in mind that for each development, there are several research groups exploring technical algorithms in response to the challenge, publishing papers, releasing source code, and generally pushing the state of the art. It is also worth noting that in addition to the "major" leagues, there is also a whole ecosystem of RoboCupJunior leagues for children in secondary school. RoboCupJunior is also constantly innovating towards improving its educational value.

In summary, RoboCup comprises a large, vibrant community that is continually pushing the state of the art in AI and robotics. While this abstract aims to give a taste of what's hot at RoboCup, the only way to gain a full appreciation is to attend RoboCup in person. Please do!

Acknowledgments

Were this a full paper, two pages of references could be included to cite the 19 volumes of symposium proceedings, and the many technical papers resulting from, or motivating and commenting on, the developments mentioned in this abstract. Due to space limitations, suffice it to thank all of the RoboCuppers who have participated over the past 20 years. Without the passion and energy of the participants, RoboCup is nothing. Special thanks to the members of the RoboCup executive committee who sent me summaries of the most important developments in their particular leagues.