The RoboCup Humanoid League on the Road to 2050

By Maike Paetzel and Ludovic Hofer

Since 1997, RoboCup has developed into a truly unique and vibrant research community advancing robotics and artificial intelligence through open competitions. Although RoboCup is best known for its original goal "to have a team of soccer robots defeat the team of World Cup champions" by 2050, it has successfully expanded to include meeting societal challenges for intelligent robots in areas such as rescue, home care, and industry applications. What unites the growing number of researchers participating in RoboCup every year is more than the 2050 goal; it is the effort to create a testbed to evaluate hardware and software solutions among leading research institutes around the world.

In 2002, the Humanoid League (https://humanoid.robocup.org/) was created to address the huge scientific and technological challenge of developing a team of intelligent humanoid robots able to play soccer on par with a human World Cup champion team (Figure 1). Robots participating in the Humanoid Soccer Competition must comply with rules regarding humanlike body proportions as well as with those related to motion and sensing abilities, which include the use of up to two red-green-blue cameras and microphones but rule out the use of laser or compass sensors. Successful play in the regular soccer tournament demands developing competitive solutions for versatile
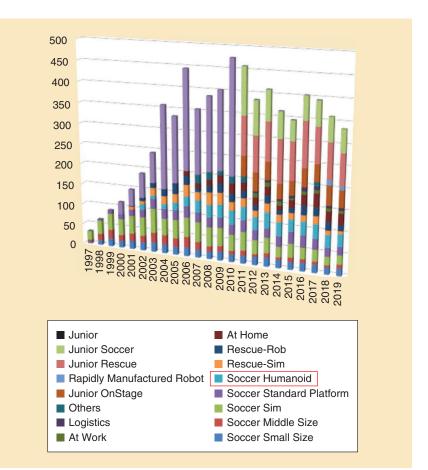
Figure 1. The number of participating teams in RoboCup challenges over the years. The Humanoid League (started in 2002) is represented as light blue. (Source: Minoru Asada, founding trustee of RoboCup; used with permission.)

and reliable humanoid motions on artificial turf, robust perception, self-localization on a symmetric field and in a dynamic environment, motion planning under uncertainty, autonomous robot behavior, and team coordination—all integrated successfully into a whole humanoid robot team.

A total of 263 researchers and students stepped up to the field from 4 to 7 July 2019 in Sydney, Australia, and competed as part of 28 teams from 14 different countries in the Humanoid League. Nearly 100 humanoid robots were distributed into three different size categories, ranging from 40 cm in

Figure 2. Various robots competing as part of the 2019 RoboCup Humanoid League in Sydney. (Source: RoboCup 2019 Local Organizing Committee, Sydney; used with permission.)

KidSize to 180 cm in AdultSize (Figure 2). In addition, a Drop-In competition was held with mixed teams formed randomly from different research institutes and groups focused on different technical challenges; the intent was to advance specific robot abilities, such as walking stably while sustaining a push or performing team play for a goal kick from a teammate's pass. Parts of the competition were streamed, and videos can be found on the League's Twitch channel (https://www.twitch.tv/robocuphumanoidleague).

The rules of the game are adapted every year to close the current gap with the official FIFA rules and challenge the perception, locomotion, and robustness of the robots. In 2019, Kid- and TeenSize teams successfully scored goals under natural light conditions, introduced in the Drop-In competition for the first time. The new challenge highlights the robustness of perception and localization algorithms running in real time on embedded robots. In AdultSize, two robots were allowed on a field that was doubled in size, strengthening the importance of more advanced perception of balls and goalposts from a greater distance, faster walking, and closer coordination among multiple agents. As explained in the champion's paper published in *Proceedings of the RoboCup 2019 Symposium*, AdultSize champion team NimbRo (http://www.nimbro.net/) developed a deep-learning-based computer vision system that is robust against different
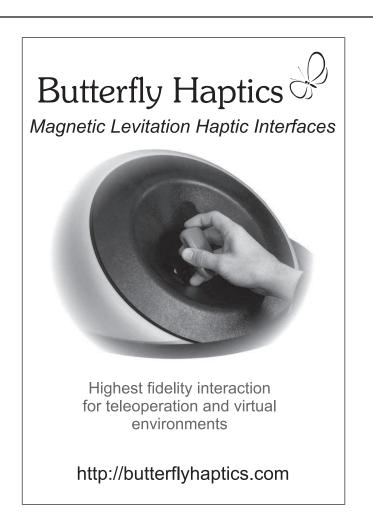

Figure 3. Team NimbRo (Germany, red) competing against team Sweaty (Germany, blue) in the AdultSize final in RoboCup 2019 in Sydney. (Source: Michael Schreiber, Rheinische Friedrich-Wilhelms-Universität Bonn; used with permission.)

Figure 4. A member of team Rhoban (France) performing a kick. (Source: RoboCup 2019 Local Organizing Committee, Sydney; used with permission.)

Figure 5. Team Electric Sheep (New Zealand, red) competing in its first round-robin game at RoboCup 2019. (Source: Humayun Khan, University of Canterbury, New Zealand; used with permission.)

lighting conditions and reliably detects balls up to 10 m away (Figure 3). Furthermore, an advanced capture step-based push recovery and a novel in-walk kick motion made the robot's games more dynamic and harder for opponents to counteract. KidSize champion team Rhoban (http://rhoban.com/) strongly improved its teamplay, too, relying on accurate odometry and taking into account the uncertainty of the ball trajectory when kicking (Figure 4).

A special concern of the RoboCup community is to keep the competition challenging for the more advanced research institutes, while encouraging participation by newly established teams. A culture of sharing open software and hardware developments, as well as lessons learned, significantly lowers the barrier for new teams like Electric Sheep (https://humanoid.science/). Within less than a year, the team was formed, developed its first humanoid robot platform, adapted sufficiently stable walking on artificial grass as well as vision and localization algorithms on a field with only white goal posts and lines, and managed to compete in the 2019 KidSize league (Figure 5). However, the fact that a robot will fall and so need to recover from falls regularly puts hard constraints on high gear-ratio reduction. Team Electric Sheep was not alone in facing this challenge, but it eventually cost them critical points in their first competition.

Following the long-term road map of the league, major steps are foreseen for RoboCup 2020, to be held in Bordeaux, France. Among others, the Humanoid Open Competition will introduce an exciting new freestyle soccer competition for all robots with bipedal locomotion. The Humanoid Research Demonstration invites researchers from academia and industry to showcase any advanced humanoid robotic abilities related to RoboCup. The new structure of the Humanoid League provides a competitive environment to benchmark humanoid robots in a task-driven setup, while allowing greater openness to sharing knowledge and welcoming newcomers in the field.