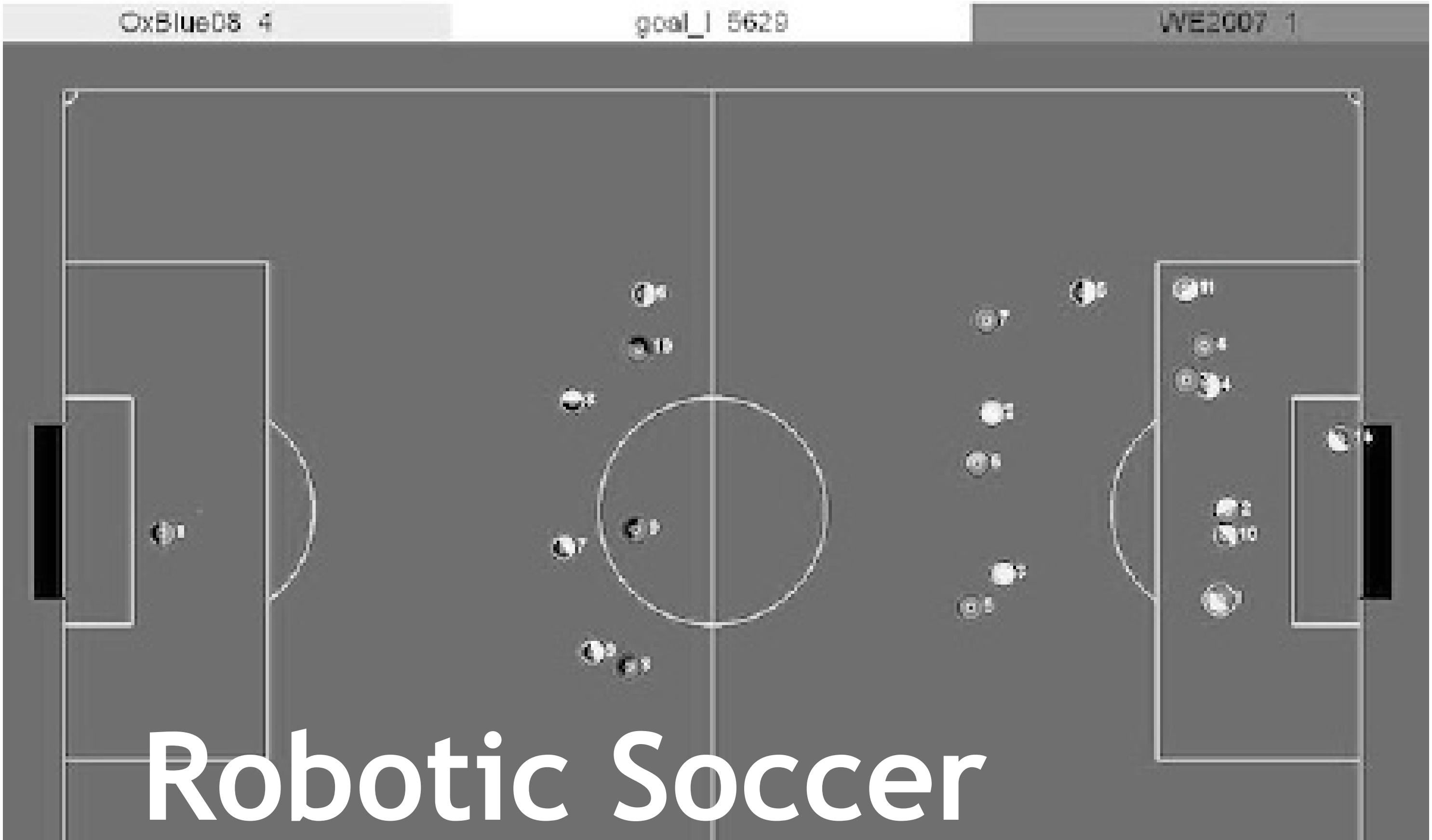


credit: http://commons.wikimedia.org/wiki/File:RoboCup-2D-Soccer-

Robotic Soccer

building the bots of the future

By Sana Raoof

"While these robots don't exactly threaten a technological singularity in the near future, their capabilities have grown from scratch in just over a decade"

The humble goal of the Robotic Soccer community is to program a team of autonomous robots to beat the World Cup winners by 2050. Sound like science fiction? The possibility of a robot beating the world champion chess player at his game seemed equally fantastical in the last quarter of the 20th century—that is, until IBM's Deep Blue defeated the reigning Kasparov in 1997. In a series of six matches the chess world and the robotics world will never forget, Deep Blue lost once, tied thrice, and "put the pedal to the medal" twice.

Intuitively, one may argue that responding to moves on a chessboard is much more algorithmic than soccer playing. Moreover, a team of robotic soccer stars would require a great deal of coordination, physical capabilities like running, kicking, passing, the ability to react, and a very accurate vision system… is 2050 too soon to achieve all this?

Contrary to iRobot-based imagination of humanoid robots with life-size height, movable limbs, and gangly legs, RoboCup soccer players are hardly mistakable for humans. The oldest RoboCup league for "small size" players consists of speedy, cylindrical, color-coded players under 16cm in height, complete with a thrusting metal kicker and shared team vision system (2). In contrast, the "humanoid league" (divided into sub-leagues of kids, teens, and adult-sized robots) is slower, roughly anatomical, and dependent upon a distributed vision system—forcing teammates to integrate their visual information.

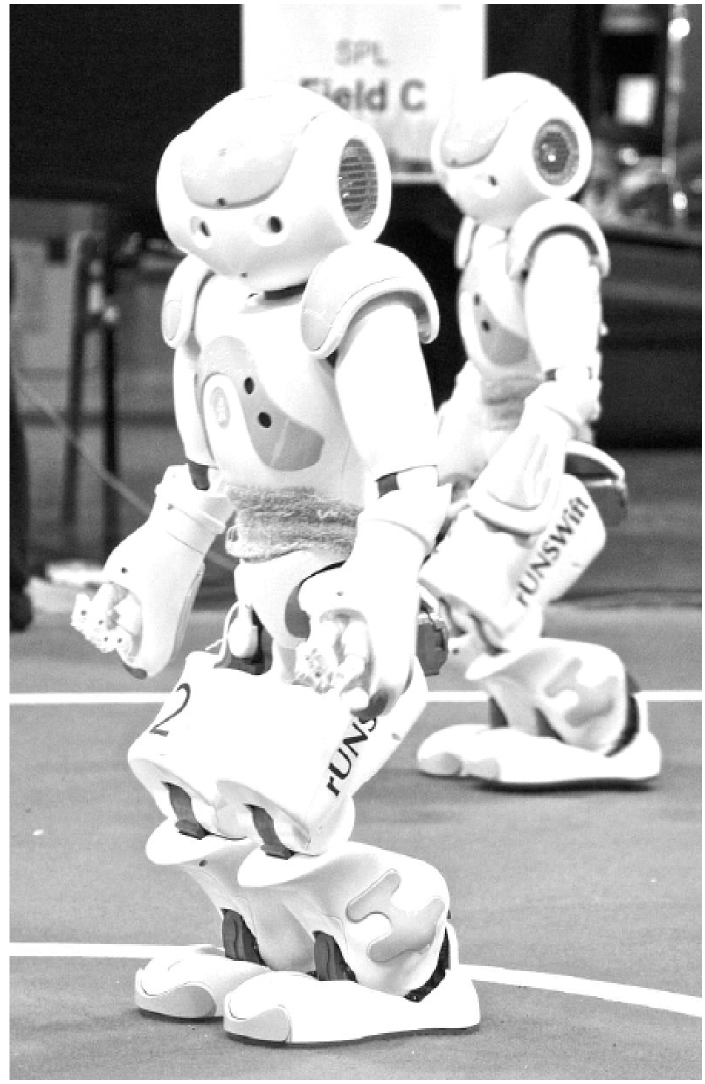
The rules of soccer-playing are quite strict, dictating the size of the fields (6.05mx4.05m), length of each game (two 10-minute halves), dimensions of goal posts (700mm x 180mm x 160mm), and the rules of play—including illegal conduct during free kicks, violence, and "unsporting behavior" (3). RoboCup teams—including the Harvard/MIT team, Robotic Futbol

Club (RFC) Cambridge—compete annually in the Robotic Soccer World Cup, which was hosted most recently by Singapore in 2010 (1). RFC Cambridge divides its RoboCup efforts into computer science and electrical engineering, allowing students to both run simulated games between virtual robots following programmed strategies and to test such strategies on Small-Size League robots at the home-field on the 3rd floor of Maxwell Dworkin (Title figure, 1).

How does one go about programming a cylindrical robot to autonomously play soccer? RoboCup teams design their own set of "STPs—skills, tactics, and plays." Skills are the lowest level maneuvers, such as "move to ball" and "kick." Higher-level tactics include single-robot commands such as "steal," "dribble to pass," and "goalie." At the top level, plays may be "aggressive defense," "risky offense," etc (3). The decision to toggle between tactics is a complex one; while a robot may benefit by switching quickly from "dribble" to "kick into goal" if a clear shot opens up, this "mind-changing" tendency causes strategy oscillations which hinder coordination and play-completion for a team. To balance predictability with opportunism, hysteresis is included in many RoboCup teams' play selector (3). Hysteresis is roughly system "memory" or history; for example, a play selection function may assign additional weight to a play that the robot had been pursuing in the previous instant when deciding which play is optimal to pursue for the next timestep. Sophisticated teams may also exploit machine learning algorithms which allow robots to "learn and adapt" dynamically, making future play decisions based on their previous performances and experiences in the field. Each team's playbook is continuously fine-tuned after simulated games and real-life tournaments; a "RefBox" is used to mediate these games to minimize human intervention in the games (2, 3). The RefBox can halt, force start, or stop all playing by wireless signal. In the case of over-turned robots, however, a human referee is needed.

"Program a team of autonomous robots to beat the World Cup winners by 2050."

In order to visualize landmarks referenced in these STPs, such as goalposts, enemy players, teammates, and the ball, roboticists use aerial video cameras and computers to communicate wirelessly with individual robots (3). In the humanoid league, each robot has two cameras on its head; wireless signals from ten such robots playing simultaneously sometimes interfere, creating a need for backup strategies in the absence of communication.



credit:http://commons.wikimedia.org/wiki/File:RUNSWift_Naos_2010.jpg

▲ **Figure 1.** A Humanoid League player, rUNSWift

Particularly tricky moves, such as passing and running between teammates, deflecting the ball off of a teammate into the goal, and variable-force kicking are exciting challenges. Precise motion planning is required for sensitive deflection shots, as is robust coordination between teammates and a degree of hysteretic stability. While these robots don't exactly threaten a technological singularity in the near future, their capabilities have grown from scratch in just over a decade (Robotic World Cup was founded in 1997). Internationally-renowned RoboCup teams like the Carnegie Mellon Dragons and Thailand RoboCup, along with up-and-coming RFC Cambridge and students in Professor Radhika Nagpal's Harvard course, CS-189 (Autonomous Multi-Robot Systems), are chasing the dream of beating the human World Cup soccer stars before 2050—one decade down, under four to go. H

—Sana Raoof '12 is a Chemistry and Physics concentrator in Pforzheimer House.

References

1. "About RFC." RFC Cambridge. Harvard School of Engineering and Applied Sciences. Web. 17 Mar. 2011. <http://www.rfccambridge.com/about.rfc>
2. "About the Small Size League." Small Size Robot League. Web. 17 Mar. 2011. <http://small-size.informatik.uni-bremen.de/>.
3. Browning, Brett. (2004) STP: Skills, Tactics and Plays for Multi-robot Control in Adversarial Environments. TS. Carnegie Mellon University, Pittsburgh.