

## Silicon Players of the Beautiful Game

By Philip Bethge

**Never mind chess -- the cool game for smart machines now is soccer. Humanoid robots stumble around the field but learn quickly. They're playing their own World Cup this week in Germany, and scientists hope machines will beat human champions in less than 50 years.**

Paul, Franz, Gerd, and the shapely Lara aren't exactly soccer stars. In fact, they're not even human. They have feet made of carbon fibers and hips with double AC servomotors, powered by lithium-ion batteries with just enough juice for two ten-minute halves. But they're preparing for a World Cup of their own this week in Germany. "Look at this -- that was no coincidence," says their inventor, Sven Behnke, pointing at a computer screen displaying the moves from a game last year against Japan's "Team Osaka." The fact that his protégés scored a single goal still makes Behnke proud.

### Robot Soccer: Germany's "Robocup"



Click on a picture to launch the image gallery (8 Photos)

He's a computer scientist from the University of Freiburg who also serves as head coach of the team "NimbRo," a group of robot athletes that may make soccer history this week. Last year the Freiburg side placed second in their league. Only the Japanese team beat them, 2-1 -- in spite of a heroic goal in the second-to-last minute.

Freiburg's robots are looking for revenge on Wednesday. The annual RoboCup 2006 takes place in Bremen this year, in parallel with the human World Cup.

The organizers expect around 400 teams from 36 countries to take part. They'll flank, dribble and score in five separate leagues. The robots have 50 different shots in their repertoire, from bicycle kicks to headers. The big clumsy humanoids are fitted out "with two legs, two arms, and a head connected to a torso," according to the robot game's regulations, and -- just like in real life -- the Germans this year have a shot at the title.

"We at least want to finish near the top," says Behnke, who has to worry about competition at home as well as teams from the Far East. The "Darmstadt Dribblers," led by Oskar von Stryk at the Technical University of Darmstadt, are the 2006 season's dark horse favorites.

"I think our robots will clearly be the fastest," brags Stryk. "Bruno" can sprint about one foot (30 centimeters) per second and functions as the Dribblers' new secret weapon. "He's got a wide-angle camera built into him," says Stryk, which means he can "see his own feet."

Playing soccer is now the great challenge of latter-day robotics: Researchers have been working for ten years to get machines to chase balls. The scientists' enthusiasm for the sport should hearten anyone who ever wished bloody shins on a soccer-innocent intellectual. Chess, in computer-science circles, these days is for nimrods -- the cool kids are on the soccer field.

"Robot soccer has replaced chess as the main problem of artificial intelligence," says Behnke. In 1997 programmers were celebrating the triumph of IBM's "Deep Blue" computer over chess champion Gary Kasparov; since then technology has moved on to the secrets of the give-and-go pass and the backheel.

### **Trickier than chess**

The rules of everyday life are far more difficult to express in bytes than chess matches or planetary orbits. A brilliant checkmate is child's play compared to the art of a free kick. "Intelligence needs a body," says Stryk, meaning that interaction with the real world is a prerequisite for intelligent behavior. Nothing's harder to program into a robotic athlete than ball control. Never mind team play.

From the opening whistle in a robot game, every machine has to fend for itself. The first step tends to be a meditative pause while current flows through the robotic brain: Where exactly is the ball? How do I get there?

Exercises at the Darmstadt Dribblers' training camp demonstrate just how puzzling these questions can be. "Bruno" is 55 centimeters high, which puts him in the "Kid-Size" League (under 60 centimeters). Twenty-four servomotors quietly hum in his joints. Sensors register arm and leg positions several times per second just to keep the machine upright.

Bruno scans with his head camera like a sniffing beast. Then he pauses. "He's found the ball," says Jutta Kiener, a mathematician and personal coach for the Darmstadt team. The machine starts to move, falteringly. Then it falls over. "The carpet's too soft," says Kiener.

What's self-evident to human beings has to be drummed into robot brains, byte for byte. Robot soccer players once responded to the starting whistle by running off the field in search of the ball. Those days are over, but perception is still a machine's main problem. From sensor and camera data the computers have to forge a split-second impression of a world in which other robots, and a ball, keep moving. Even now it's sometimes better to trust happenstance; a blind robot took third place at last year's Robocup in Osaka.

The simplest actions are still tricky for mechanical athletes. Robot leagues have existed for four years, but it's still something of a miracle when a machine can walk or even run on two feet. "I think there will only be a few teams in Bremen that can manage to get their players all the way across the field one time during a game," says Stryk.

In fact, the most interesting plays the robot league now has to offer sports fans are scenes of robots tripping over each other in slow motion. The game is usually over when a robot falls. Bruno doesn't give up so easily -- he wrenches himself around until he's on his feet again -- but this behavior can burn up whole minutes of play.

"Soccer's an extreme sport," says Stryk. Good thing the competition also makes mistakes. Behnke in Freiburg learned long ago to concentrate on essentials. "We're happy enough when the ball rolls in the right direction," he says.

If the robots look hesitant on the field, their creators are confident. They're laying the groundwork for a new generation of robots. A machine that can successfully kick a goal will open the way for machines that can put out fires, drive ambulances or clean homes.

Human-shaped robots in particular may have a big future. "We've built a world around our own bodies," says Behnke. Only robots with human proportions and extremities can climb steps, work light switches, or use vacuum cleaners. "Eventually robots will learn to do things by imitating us," he says. "And that will only work if they're built the same way."

### **Dreaming of a real World Cup in 2050**

In Bremen, the machines aren't self-teaching; they'll do only what they've been programmed to do. Robots in the Kid-Sized League will play in primitive teams, two-on-two. The field measures four and a half by three meters (or about 15 x 10 feet). A special demonstration game between two three-machine teams is also planned. The robots will use a wi-fi network to exchange information about the ball's position and exhibit a low level of team play.

The inventors also like to give their mannequins feelings. After a lost match the Darmstadt Dribblers shake their heads and arms to show frustration. The inventors' long-term plans, however, don't involve losing games: Robocup co-founder Hiroaki Kitano hopes an eleven-humanoid team will beat reigning (human) World Cup champions by 2050.

Computer scientists figure the taller robots from the "Teen-Sized" League (under 130 centimeters, or four feet) will grow into a future dream team because they have the most raw talent. Right now, though, the tall robots are also the most simple-minded: They compete only in penalty kicks, obstacle courses, and foot races. A full soccer game is too much for their silicon brains.

A Freiburg Teen-Sized player called "Robotinho" stands about a meter high. His trainers hope he'll win at penalty kicks. Darmstadt's Teen-Sized Lara, on the other hand, is a sleek and shapely state-of-the-art machine who may or may not give Robotinho some stiff competition. Instead of motors she has 34 muscles made of so-called "shape-memory" wires. These wires contract under electrical charges: They function almost like biological muscle fibers.

But Lara's still a little clumsy. "We'll be happy if she takes a few steps at the Robocup," says Stryk, who believes she'll come first in exactly one discipline this year.

"She'll easily be the most beautiful robot at the tournament," he says.