CULTURE FEATURE VIDEO

Real steel: the broken robot necks and baby steps of RoboCup 2012

Face-planting towards the goal, the world's best soccer robots battle it out in Mexico City

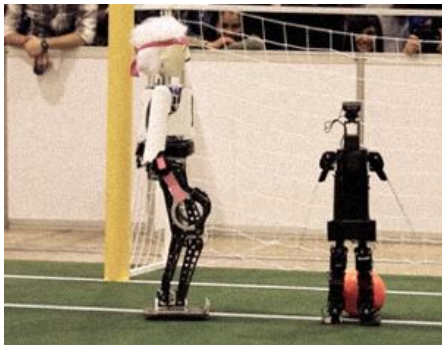
By Paul Miller (http://www.theverge.com/users/futurepaul) on September 7, 2012 10:21 am Email (mailto:paul@theverge.com)

Marcell Missura, a robotocist, is on his stomach staring into his laptop. A robot sits next to him. Marcell clicks and types, then sits up. He holds his hands out to spot the robot, like it's a child attempting to walk for the first time. Tapping a button on a wired Logitech game controller sends the robot walking with a rolling gait that swings its upper torso in a wide arc. Before the robot's wayward momentum sends it tumbling, Marcell halts it with another button press. Marcell clicks and types, just tweaking. This time, the robot walks a bit better. He tweaks and tries again. The robot walks a bit worse. He tweaks again. The robot nearly falls, and Marcell catches it gently, like an egg. Marcell presses a switch in the robot's neck rendering its limbs limp, and he folds it onto its haunches.

The robot is named Copedo, but Marcell never speaks to it. Copedo can't listen, and can't talk — it only understands variables, relayed through an Ethernet cable. About as tall as a six-year-old, Copedo has oversized Erector-set-style legs and a tube of foam around its middle. On its back is a Sony Vaio UX computer, operated by stylus. Copedo's face looks like a manequin moonlighting as a clown, and the robot has hoops for hands, expressly designed for picking up soccer balls.

Video

Marcell is very German. He has blond hair, a melodic accent, and lives in Bonn, in the far west of Germany, where he's working on his PhD at the local university. He lives a quiet life in a calm town, biking to work and staying near relatives, but seems just as much in his element in the hectic environment of RoboCup. This is his fourth time at RoboCup, and Copedo is his fourth robot in as many years. At Bonn he works with Michael Schreiber, whose prolific engineering keeps up with Marcell's appetite for experimentation. Michael isn't here this year, so Marcell is working with a couple new teammates, showing them the code and teaching them the ropes. Most of his time is on the field with the robots, coaxing them to motion.



Now Marcell is teaching Copedo how to kick. It's much stronger than its walk, and the mid-size soccer ball rolls forward several feet. I congratulate Marcell, but he returns to his computer unimpressed. "What would you expect from a kick? It has to be able to score a goal from any position," he grumbles.

Marcell likens teaching a robot to walk and kick to sculpture. It's sculpture with variables. Copedo has 35 tweakable numbers that define its kick alone, with hundreds of hard-coded parameters that cascade from those. In simulation, 35 variables are a challenge, but in real life, those 35 interact with the infinite variables of real life. A dozen or so motors are held to an imperfect, flexing frame by screws at different tensions, all stumbling over a nearly flat soccer field, covered in felt.

Copedo falls, and Marcell keeps sculpting.

Welcome to RoboCup

RoboCup 2012 was my first RoboCup — my knowledge of last year's competition in Istanbul and prior matches has all come from YouTube and second-hand accounts. I picked up my credentials at an improvised "Press Registration" table in the multi-floor building dubbed the "Pepsi Center" behind Mexico City's World Trade Center, and wandered in. It had the usual bland mix of grays and blues required in convention halls worldwide. An unrelenting mix of Switchfoot songs played on the loudspeakers to lift the spirits of the competitors -- a thousand or so respectable computer scientists and mechanical engineers, whose robots were about to make a butchery of "the beautiful game."

In front of me stretched a sea of folding tables draped in blue tablecloths, each assigned to a different team. Most tables were drenched in disassembled robots and spare parts. Every year someone at RoboCup starts a fire with one of its battery charging stations, and this year looked like it would be no exception.

RoboCup's multiple soccer "leagues" are broken down by size and mechanics: from tiny wheeled robots up to full-size humanoids. The Humanoid League, where I spent most of my time, was all custom-built robots, and therefore required the most maintenance, the most tables, and the most battery fires.

All of the games (and most testing) take place on small soccer fields of green felt, which change in size depending on the type of robot competing. Roboticists sleep at their tables, fighting jetlag. The games wouldn't start until Wednesday, and so Monday and Tuesday were spent in earnest calibration, with cables, robots, laptops, and sock-clad roboticists sprawled across the fields.

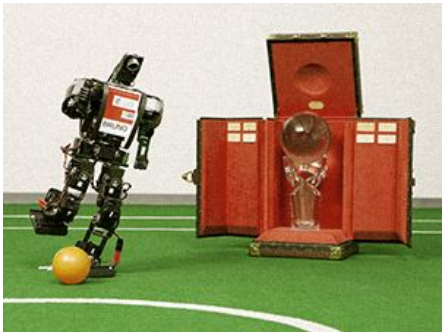
After assembly, the robots are taught very carefully what a ball looks like, based only on its color. Every flicker, burned out bulb, and hue variation confused the robots, and the roboticists would curse at the yellow-gray ceiling like a rain cloud threatening a baseball game. Then they'd take another bite of Domino's pizza, pull up some code, and start another round of calibration.

RoboCup's competitors vie for the Louis Vuitton Best Humanoid Award, filled with a Baccarat crystal globe and encased in the iconic monogrammed LV lettering, but they wear t-shirts emblazoned with university names and nylon cargo pants that convert into capris.

ROBOCUP'S COMPETITORS VIE FOR THE LOUIS VUITTON BEST HUMANOID AWARD

A simple game of soccer

THE ROBOT DIVES TWO SECONDS TOO LATE... IN THE WRONG DIRECTION



RoboCup started twelve years ago, with an absurd goal to field a team of soccer robots against the human World Cup champions in 2050... and win. Right now the robots couldn't beat a team of toddlers.

A bit like a regular soccer match, robot soccer has two teams, two goals, a field, a ball, players and a referee. On each team's sideline is a long table that acts as a makeshift robot hospital. Across from the teams are metal bleachers, filled with a rotating cast of fans.

Each team has a robot handler, which picks up “malfunctioning specimens” off the field and hands them to the robo-hospital, or just places them in time out until their penalty time is over. The handlers stay busy. Both of them, along with the referee, wear black pants and black socks on the field, so not to confuse the robots.

The robots see the game as a "state machine," a flow chart of best-case scenarios. A state machine asks "what is my status?" and then executes a routine based on that status.

Do I see a ball?
If yes, then go to it.
Am I near a ball?
If yes, then kick it at the opponent's goal.

If the robot is confused about its status, all of its actions will be incorrect — and even the right status doesn't guarantee a useful action.

The whistle blows, all robots run at the ball simultaneously, blocking each other — including their own teammates — from reaching it. They fall. A robot gets up and kicks the ball towards the goal, but doesn't register the mayhem at its feet blocking the shot.

One robot decides the orange notebook I'm holding on the sidelines is a ball and goes after it. Another thinks the concrete pillars in the convention hall are goal posts.

The goalie's state machine determines it should make a dive to stop the ball rolling toward it. But it dives two seconds too late... in the wrong direction. And now it can't get up. The confused robot is pulled from the field, leaving the goal completely open.

Teams play with two, one, or no robots on the field. There are countless open shots, open goals, and missed shots on open goals. For some teams, success at RoboCup would be scoring a single goal in a game. For other teams, a single kick without falling over would be a triumph.

The real world

Nobody *needs* a robot that can play soccer. The point of RoboCup is that if a robot *could* play soccer, it could also probably do other things well. Useful things. RoboCup started with caninoids in 2000, and tiny humanoids emerged later, not much more impressive than Tickle Me Elmo. Now the Humanoid League has KidSize, TeenSize (like Marcell's Copedo), and AdultSize robots, each in various stages of maturity.

In the meantime, The robots learned to survive falls, get up under their own power, and do other marvelous things — all in the name of soccer. A game of soccer puts a robot on a flat surface, with a narrow purpose (chasing and kicking a ball), but there's plenty that can go wrong: the real world just can't be predicted.

Here's a fable I heard: "The Pizza Boxes and the Light Switch." A human carrying a stack of pizza boxes encounters a light switch. Lacking a free hand, the human kicks at the light switch to flip it on. A robot carrying a stack of pizza boxes encounters a light switch, but has no "program" that explains the careful motions and balance shifts required to kick on a light switch. The simple elegance improvised unconsciously by a human is inconceivable for a robot that relies on pre-programmed routines and uninventive state machines.

A robot can only be truly useful to humans when it can operate in the "real world," in the same environments, without a script. Wheels can only take robots so far into those realms. "If you have a street, the wheel is a great invention," one roboticist explained to me.

Honda's Asimo is widely considered the most advanced humanoid in the world. But Asimo's most iconic YouTube moment isn't one of its myriad best-in-class accomplishments, it's a horrifying fall off a staircase during a public demo. The crowd gasped, and Asimo's handlers rushed to block the scene with screens.

Asimo doesn't compete at RoboCup. There are no screens to wheel in and cover up failure. Each fall is on display for the world to see.

And "everybody falls sooner or later," as Dr. Sven Behnke puts it, Marcell's supervising professor at the University of Bonn. No matter how good your theories are, how clever your state machine is, or how elegantly your walking algorithm's variables have been tweaked, gravity always wins.

DARPA's big step

HUMANOID ROBOTS WILL BE REQUIRED TO DO THINGS LIKE DRIVE A REAL CAR, CLIMB A LADDER, AND OPERATE A POWER TOOL TO BREAK THROUGH A WALL

There were no streets at the Fukishima nuclear cleanup in Japan, and the tank-tread, best-in-class iRobots deployed there struggled with the stairs, with doors, and navigating over debris. Then the connection would drop, and the human-operated robot would have no idea what to do.

"So many people were asking 'where are the robots that go into there?'," said Dr. Oskar Von Stryk, a professor at Darmstadt in Germany, "and I honestly have to say that they aren't there because nobody wanted them. You can't earn money with it, there's no market."

RoboCuppers have been building robots for years that have no "real world" application, but the Fukishima disaster has spawned a new game-like test for robotics, one that goes far beyond soccer in complexity and financial incentives: The DARPA Robotics Challenge.

DARPA is unaffiliated with RoboCup, and nothing that goes on at these games has any bearing on a DARPA entry — but I couldn't escape the conversation all week.

Similar to its autonomous car challenge from a few years ago, the US Military's DARPA program is sponsoring a competition where humanoid robots will be required to do things like drive a real car, climb a ladder, and operate a power tool to break through a wall. The funny thing is that even the basic requirement of walking across uneven ground like grass or broken sidewalks is "beyond the state of the art," says Jacky Baltes, the chief referee at RoboCup.

But still, RoboCup veterans feel like they have a shot at the prize. For one, DARPA's chosen "standard platform" for the competition is Boston Dynamic's spry PETMAN, which has only ever been shown in a lab, and it requires externally-supplied pneumatic power. In contrast, all the RoboCup robots carry their power with them. When it comes time to complete the challenge outside of simulation, which will be roughly two years from now, PETMAN might no longer be the strongest hardware.

More importantly, RoboCup participants feel battle-tested. The best ones don't just win because they have the best robots, they win because those robots work when they're needed — not just one time in 100 for a YouTube demo.

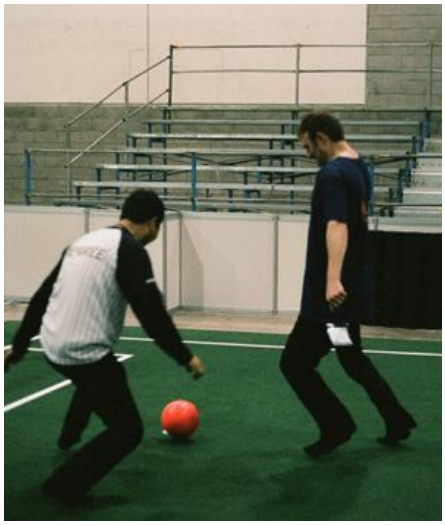
Learning to fall

"You have to look at every change and discard most of them," Marcell explained. It's one thing to come up with fancy new functionality, but it's another thing to integrate it into a complicated system that has to work when the whistle blows. "It's like everyone working on a house of cards... together."

"THE WHOLE PROGRAM OF THE ROBOTS IS BASICALLY LOADED INTO MY BRAIN."

Marcell's trademark piece of apparel is an ugly, oversized sweater jacket that acts as simultaneous lab coat, painter's smock, and security blanket. It billows as he jogs between his work table and the soccer field, alternating between sitting and laying as he pours over his code — which is from 7AM to 11PM every day this week. He dreams in code, too: "The whole program of the robots is basically loaded into my brain."

He likens his walking algorithms to recipes: when you find a good one, with the measurements just right, you want to be sure to save a copy. He's built Copedo's walk recipe from scratch "100s of times," and it's "quite a pain in the butt."



There's all sorts of science required to build a robot, but when you're on the field, you just have your eyes. There's "nothing to calculate," explains Marcell, "you have to look at the robot." The skill, of course, is knowing what to look for. Marcell admitted he could spot problems in robots other than his own: "sometimes I have the impression 'this should have a little lower of a frequency,' or 'that one has the legs spread apart too far.'" But he keeps his suggestions to himself because he doesn't want to seem rude. Whether politeness or competitiveness was holding him back, Marcell's robots walked literal circles around the competition all week.

Marcell claims that his lab-built recipe didn't work at all when he first arrived, but midway through the first day, Copedo had the best walk in the building. Each step was stable and strong, and reminded me of an adult wearing a heavy backpack. But as Marcell kept pushing its speed, Copedo started to fall.

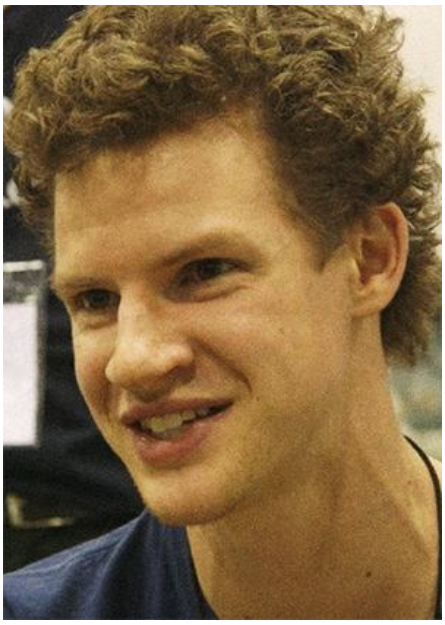
"Anything I do makes it worse," he said.

We hunkered down on Marcell's corner of the test field and observed. He tried another kick, and the robot shifted its weight to one side to counterbalance the motion. It looked precarious, and when it returned to two feet, Copedo took a second or two to stabilize laterally, swaying like an upside-down swing.

Marcell startled, eyes wide, and then dove into his computer.

He'd forgotten to turn on "damping," he explained. In Copedo's case, damping is a routine that causes the legs to actively resist the swaying motion, and the robot had been doing without that algorithm. Marcell pulled up the source code, tweaked, and recompiled. When Copedo tried another kick, it stabilized almost instantly after its kick.

Marcell's interest isn't in just creating the perfect, optimal walking algorithm. His PhD research is in teaching a robot how to *stagger*. How to right itself when the conditions stray from optimal. The real world is non-optimal, and RoboCup is a brutal, week-long reminder of that fact.



STEVEN SOUNDED LIKE A SPACESHIP ENGINEER, STRETCHING A PHOTON DRIVE TO ITS LIMITS

The next table over, Steven McGill, from U. Penn, runs the dominant Darwin-OP KidSize team, a joint effort between Virginia Tech and U. Penn. But he also brought a new robot this year: Darwin XOS, which is Team Darwin's first TeenSize entry. The robot was as fresh as they come: Virginia Tech had machined the final parts only a week before, and when I first spotted the robot, Steven was still teaching it which way gravity was pointed.

When they finally got XOS "walking," it looked like it was staggering through death throes after taking a bullet to the chest, or possibly in need of a bathroom. Steven works with his brothers, who he operates like a command line interface. He was tweaking "velocity limits" in OS X's Terminal, while they babysat XOS in case it fell.

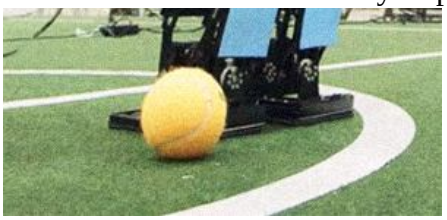
"Dude, the velocity, I can get it up to .06 now." Fingers flew, more tweaks were made. "Forward bias, definitely a forward bias." Steven sounded like a spaceship engineer, stretching a photon drive to its limits. XOS started to fall forward. "I was pushing it, I was pushing it!"

"What was that up to?" asked a brother.

".08, putting it back to .06," said Steven, adrenaline still pulsing. "Save save save..."

On .06, XOS started really walking. Not Marcell / Copedo-good, but still pretty good. I cheered, Steven checked again that he'd saved, and then he looked around to see if anybody had seen. There were few witnesses. Steven and I scrambled for cameras but by the time we were ready to shoot, XOS wasn't able repeat its performance.

The team blamed overheating motors and rested XOS, but I never saw it take another good step. As the week wore on, it seemed XOS's inefficient walk and weak power-to-weight ratio was burning out its actuators.



Saturday, I watched in agony as the Darmstadt Dribblers, Darwin-OP's primary rival in the KidSize league, lost their semifinal match with most of their robots on the sideline. The game had been a tight back-and-forth until the end. "The intense is killing me," said a Korean woman next to me, as the score tied up for the third time. The intense was killing me, too. But then the opponent, CIT Brains, scored a couple uncontested goals. Darmstadt students frantically pumped compressed air into the joints to try and cool off their robot's motors, rushing to get a working Dribbler back on the field before the clock ran out, but ultimately the aging design just couldn't handle the strain.

A house of cards indeed.

Playing it safe

RoboCup's simultaneous strength and weakness is that to win, you have to leave your bleeding edge experiments at home and bring something that just works. Darmstadt has been bringing the same KidSize soccer robot to RoboCup for the past five years, and there's no replacement on the way. In the AdultSize competition, Virginia Tech coasted through to a win with Charlie-2, which won the Louis Vuitton award last year and underwent few changes for this year's competition. Why risk knocking down the house of cards if you're winning?

"AI is not about doing the optimal thing," Dr. Daniel Lee told me, who heads the robotics program at U. Penn and helps advise the Virginia Tech guys as well, just "never do the stupid things."

Now that TeenSize robots like Marcell's can survive falls, and even get themselves up off the ground at times, TeenSize seems like a natural evolution from KidSize — like the move from caninoid to humanoid was last decade. But just four TeenSize teams came this year, and only Marcell's Nimbro bots and the slick, minimal CIT Brains humanoids were competitive.

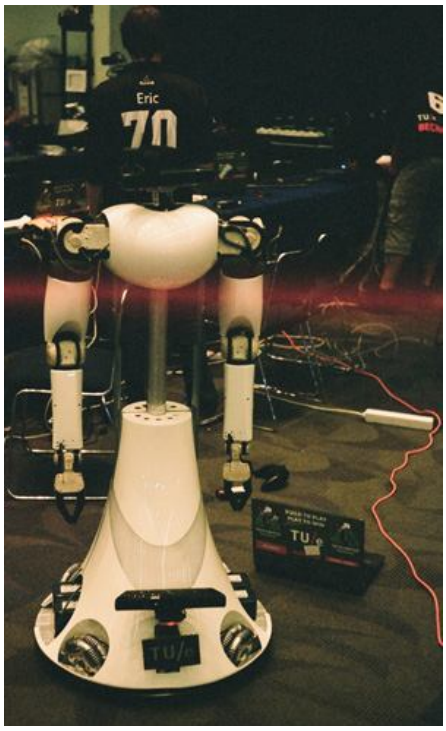
Many participants agreed that TeenSize is the "optimal" move for RoboCup, but the robots are exponentially more expensive than KidSize robots, and they don't get as much press as AdultSize robots. Now with DARPA looming, next-gen AdultSize robots -- like the promising ones in the works at Virginia Tech and Darmstadt -- will be even more important.

Marcell is building a TeenSize Open Platform robot, which he hopes to get built and sold by Robotis, like it currently sells the KidSize Darwin-OP. Maybe it will help. But the fact also remains that these humanoids are desperately dumb. It seems silly to spend $20,000 or $30,000 on a robot goalie that dives in the wrong direction.

"AI IS NOT ABOUT DOING THE OPTIMAL THING — NEVER DO THE STUPID THINGS."

Even Kinect can't save them

"PLEASE LOOK AT ME.
PLEASE LOOK AT MY EYES."



At RoboCup, the real brains are in the @home competition. The robots compete at domestic chores like recognizing humans, handing them objects, avoiding collisions with furniture, and cleaning up carefully placed messes. They're aided by laser rangefinders, high-powered laptops, and Kinect sensors for heads.

But even the best brain is at the mercy of its state machine. Most of the @home robots failed on the starting line of their very first test: an open door. The whistle would blow, the clock would start, and $20,000 or so of machinery would stand still, asking itself "is the door open?" and answering itself with a false-negative.

In a later @home competition, a robot stood still for three minutes in front of a judge it was supposed to be recognizing. "Please look at me," it intoned synthetically, wanting a better look at the judge's face. "Please look at my eyes." I squirmed in the audience. Human and robot stood face-to-Kinect sensor until the clock ran out, the request on loop. "Please look at me. Please look at my eyes."

Thankfully, I also saw some amazing things in @home. Robots managed to take verbal drink orders, pick the correct beverage among a lineup of choices, and then bring it to the human that requested it. Robots watered plants, picked up trash, and, on occasion, went through open doors.

In my favorite performance, Marcell's colleague Jörg Stückler's Cosero followed a judge through a crowd and entered an elevator. I sprinted with a few dozen other observers to an escalator and downstairs, where we craned our necks, cameras poised, to see if Cosero would manage to make it out of the elevator. It did, but the changes in lighting downstairs stopped it in its tracks.

The elevator challenge had originally been slated for a freight elevator, but the elevator would stop a couple inches lower than the floor — making it too dangerous for the wheeled robots to navigate. And so the robots used the handicap elevator instead.

It's about failure

One time, after thirty minutes of watching Marcell tweak variables, I suggested that robotics might require some patience. "Oh, definitely," he said. "It almost never works."

And that about sums up my experience at RoboCup. The fear of failure keeps some high-profile researchers from even attending: "It's not easy to win in RoboCup because there can always be things that go wrong, so it might be scary to some people who don't want to lose face in that respect," says Dorian Scholz of Darmstadt.

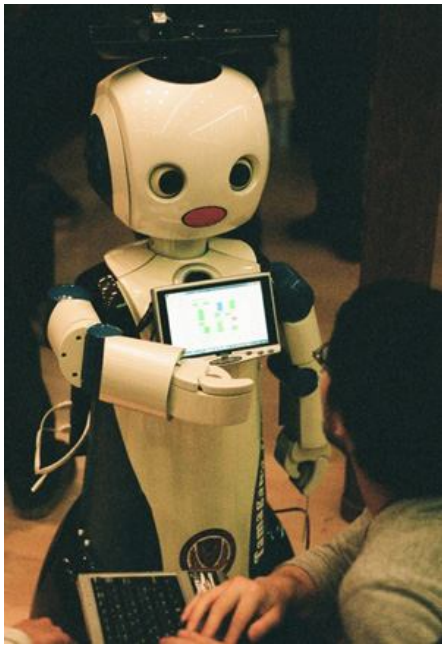
Most of the participants at RoboCup don't get much solid "science" out of their efforts, either. Sometimes it's hard to discern what the point of all this is: @home robots stumped by doors, soccer robots spending more time perplexing over a ball than kicking it... and no $3 million DARPA prize at the end to perpetuate the research: just bragging rights.

"It's a bit fuzzy over the years," admits Sven, "but still I think the people here are interested in autonomous robots and advancing the state of the art of these." RoboCup seems less about making better robots than it seems about making better roboticists. In the lab "you never get this close to it," says Marcell.

The number of spectators slowly grew during the week. There were field trips of middle schoolers, countless teenage volunteers, junior competitors who wanted to check out the real thing, and families visiting the convention hall as if it were a petting zoo. They filled the bleachers, belting out soccer chants in Spanish, applauding successful kicks, gasping when they went awry, and cheering wildly for goals.

Occasionally, a robot goalie would dive in the right direction, at the right time, to make a save. The place would go nuts, with every fan and every participant — from both teams — congratulating the robot. Of course, the robot couldn't hear them. It probably didn't even know if it had made a save or not. But the roboticists heard.

"SOMEHOW... I GOT LUCKY. IT WAS BETTER THAN PRACTICE."



Marcell remained undefeated throughout RoboCup. Not only did he win all of his games — his final match was against CIT Brains, whose last surviving robot had a broken neck, and lost 6-3 — but he also aced the technical challenge. It threw a ball, made a pass, and dribbled through cones, earning the maximum score. Marcell was jumping up and down, looking like he was holding back a scream of triumph. "It went as good as it can go!" he exclaimed. "I fixed it!" And then, suddenly, the modest Marcell returned.

"Somehow... I got lucky. It was better than practice." If it was luck, it was the first I'd heard of all week. The perfect performance in the Technical Challenge clenched the Louis Vuitton trophy for Marcell. Unfortunately, the trophy didn't make it past customs in time for the award ceremony. The valuable totem also requires high-end security at all times, and Marcel's university has opted to avoid the expense and leave it in Japan. He might never touch his prize.

Unlike almost everyone I talked to, Marcell wasn't going to try and compete in the DARPA challenge. "RoboCup already takes too much time," he said, and he has a 16 month old daughter. "I don't want to be away from my family."

Back in Germany, Marcell's wife is pursuing a PhD on the topic of video game difficulty. She has her own papers to write, so when Marcell returns home, he's on full time daddy duty for a week. Then he gets back to teaching robots how to walk, fall, and walk again.

RoboCup, like for so many participants, was Marcell's vacation. Now it's back to work.

Image of Bruno and the Louis Vuitton Best Humanoid Award 2009 courtesy of the Technische Universitat Darmstadt (http://www.sim.informatik.tu-darmstadt.de/news/robocup2010/) and the Darmstadt Dribblers (https://twitter.com/Dribblers) . Photo credit Katrin Binner.

THERE ARE 50 COMMENTS. LOAD EM UP!