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PARC's Mark Yim thinks robots should be made from small, simple, redundant modules.

Smaller pieces, smarter robots

PARC scientists substitute the power of mathematical computation for the properties of physical matter

By Bob Sullivan
MSNBC

PALO ALTO, Calif., Nov. 27 — In "Terminator 2: Judgment Day," the T1000 "liquid metal" robot spends the movie dripping his way through locked doors, oozing through impossible barriers. This morphing from human form to liquid and back again defies physical law. But not Mark Yim's laws. As the scientist at Xerox's Palo Alto Research Center sees things, a fleet of tiny, not-so-smart robots might do the trick. Yim thinks if you build them small enough, and you teach them to work together, they'll be morphing their way through earthquake rubble within a few decades.

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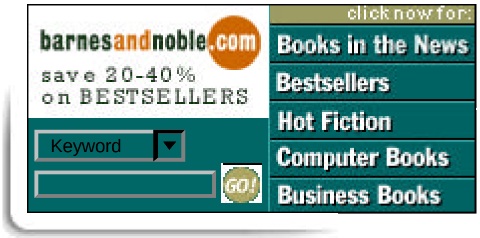

Xerox PARC's John Gilbert describes PARC's "smart matter" research.

FIRST LET'S GET this out of the way. Yim is hardly inventing "morphing time-traveling killer robots." Right now, he's just trying to get his overgrown erector sets to move at all. His biggest frustration: Robotics is one area where science fiction really is way ahead of science.

"When you watch TV or you watch movies, you see robots that can do anything — that are people, that are T2," bemoans Yim. "But in real life, getting robots to do anything is really hard."

That said, Yim has already built a working, morphing robot. It's a set of metal modules that rolls across flat terrain in a circular treadmill shape and can then unwind and flop into a snake fit to crawl down into a hole. This kind of smart locomotion has every NASA scientist salivating.

The elusive, useful robot has been a target of scientists and hobbyists since science fiction shows like "Lost in Space" teased us with the possibilities. A flood of work has gone into building androids — machines that look and work like humans. But progress has been slow. Sure, 100 teams of soccer-playing robots showed up for RoboCup '98 in Paris. But the truth is our large, complicated machines are clumsy — they keep tripping over pebbles, falling down stairs and crushing glasses they pick up.

Enter Yim, who not long ago was a Stanford graduate student with a taste for Schwarzenegger flicks. Yim's work, inspired by science fiction, examines the questions of robotics in a much more fundamental way.

STORY Part 1: When computers will disappear
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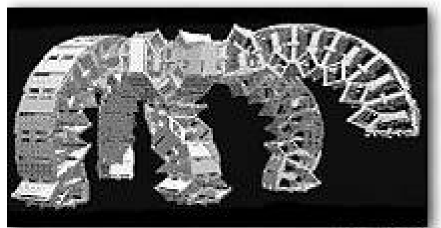
The key to building smart robots, he says, is to make them out of small, not-so-smart, modular pieces — lots of identical bots that have very little use by themselves but together can change shape and are smart enough to change their function.

Yim's dream is such a "modular robot" will one day be the key member of any search and rescue team. It could crawl through the most awkward rubble after an earthquake, sniff and listen for survivors, find one, then morph into a support structure around the victim to prevent further injury from falling debris.

Yim's work in modular robotics draws on an overarching theme at PARC — distributed computing. Instead of having one large computer with a central processor controlling all the parts, the parts themselves are smart. Xerox's pet name for this — "smart matter."



Xerox PARC

A robot of about 100 modules like this model could move in a variety of ways.

Smart matter is all about trading physical problems for mathematical problems, taking advantage of computers' affinity for math.

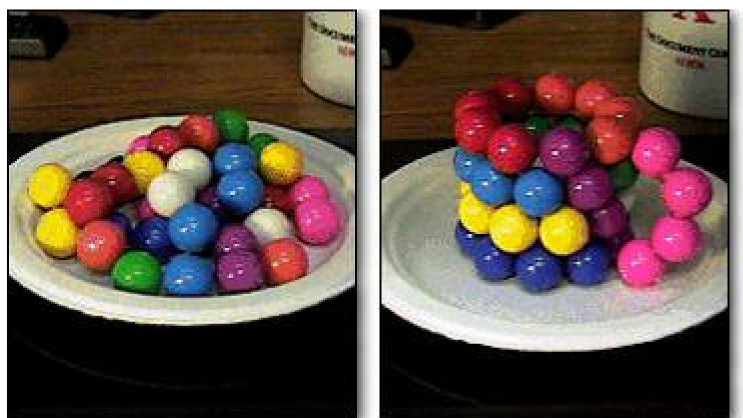
Take a steel beam. If you wanted to make it stronger, capable of supporting more weight, you'd probably just make it bigger. But smart matter scientists at PARC have tripled the strength of a steel beam by adding a row of smart electronic devices along each end. Sensors notice if the beam is buckling to one side and tell an actuator to nudge it back to vertical, keeping the weight atop it perfectly balanced. As smart matter director John Gilbert says, "It's trading off a physical mechanical resource for a computational resource."

Xerox PARC's Mark Yim describes how simple machines can work together to accomplish complex tasks.

Here's another example — the bane of Xerox's existence is jammed copiers. Copiers eat paper because the complicated system of belts, rollers and clutches inside is a very mechanical arrangement subject to breakdown.

Smart-matter researchers at PARC are working on a copier that moves paper along its path using thousands of tiny air jets instead. The jets have to be "smart" — they must be able to change direction as the paper flies by in order to push it along, then snap back in place to catch the next piece of paper.

Back to robots: It's a long leap from smart air jets and strong metal beams to liquid-motion robots. But the principles in smart matter and modular robotics are the same — combining sensors, actuators and some computing power to create micromechanical electrical systems (MEMS) that work together.



Xerox PARC

Imagine these gumballs are little robot modules sitting on your desk. You could command them to form arbitrary shapes -- though this one doesn't really hold water..

"The idea is if you can shrink these down, then things become really interesting," Yim says. "If you have millions of these and they're all kind of rolling around each other, you can have it form arbitrary shapes. "

There are some obvious advantages to modularity — like the shape-shifting already mentioned. Then there's the advantage of redundancy — such a modular robot would almost be able to heal itself.

Video: PolyPod morphing

- **Changing form:** From snake to spider (1.8M)
- **Like a slinky:** Head over heels (221K)
- **Workhorse:** Carrying heavy loads (485K)

NOTE: Videos live on the Xerox Parc Web page and are in MPEG format.

"If some of these modules break, you can just throw them away and keep going," says Yim. "Graceful degradation." Almost as important — identical, interchangeable modules will be much cheaper to manufacture.

But there are some big leaps to be made as Yim tries to teach the world's clumsy robots a little grace. While "smart" MEMS exist, they're not in his model robot yet — it's controlled by a central processor. Once each moving module is smart on its own, how will it communicate with others? And the biggest question of all: How will we tell them what to do?

"How do program them when you have millions of them? The real difficult problem is ... how do you control them," Yim asks.

Most of the funding for his efforts to find those answers comes from a contract with the U.S. Defense Department. But after that money runs out, Gilbert figures the next batch of funding could come from Santa.

Coming soon to a store near you, the first real-life incarnation of modular robotics — Yim's morphing erector set as the coolest toy on the block.

"The toy market is a very cost-sensitive market, and so being able to very inexpensively batch-fabricate something is absolutely crucial," Gilbert said. Which is why Yim's work is focused as much on economy as it is on electronics.

As it turns out, kids and science fiction fans are a bit more tolerant than scientists. They won't mind so much if robots they build keep tripping down the stairs or don't quite follow orders.

Which is why long before Yim's modules make it to the moon or Mars, they're likely to make it into your living room.

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- INTERNET Morphing robots in the extreme
- INTERNET Mark Yim's modular robotics site
- INTERNET Cool robot of the week
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