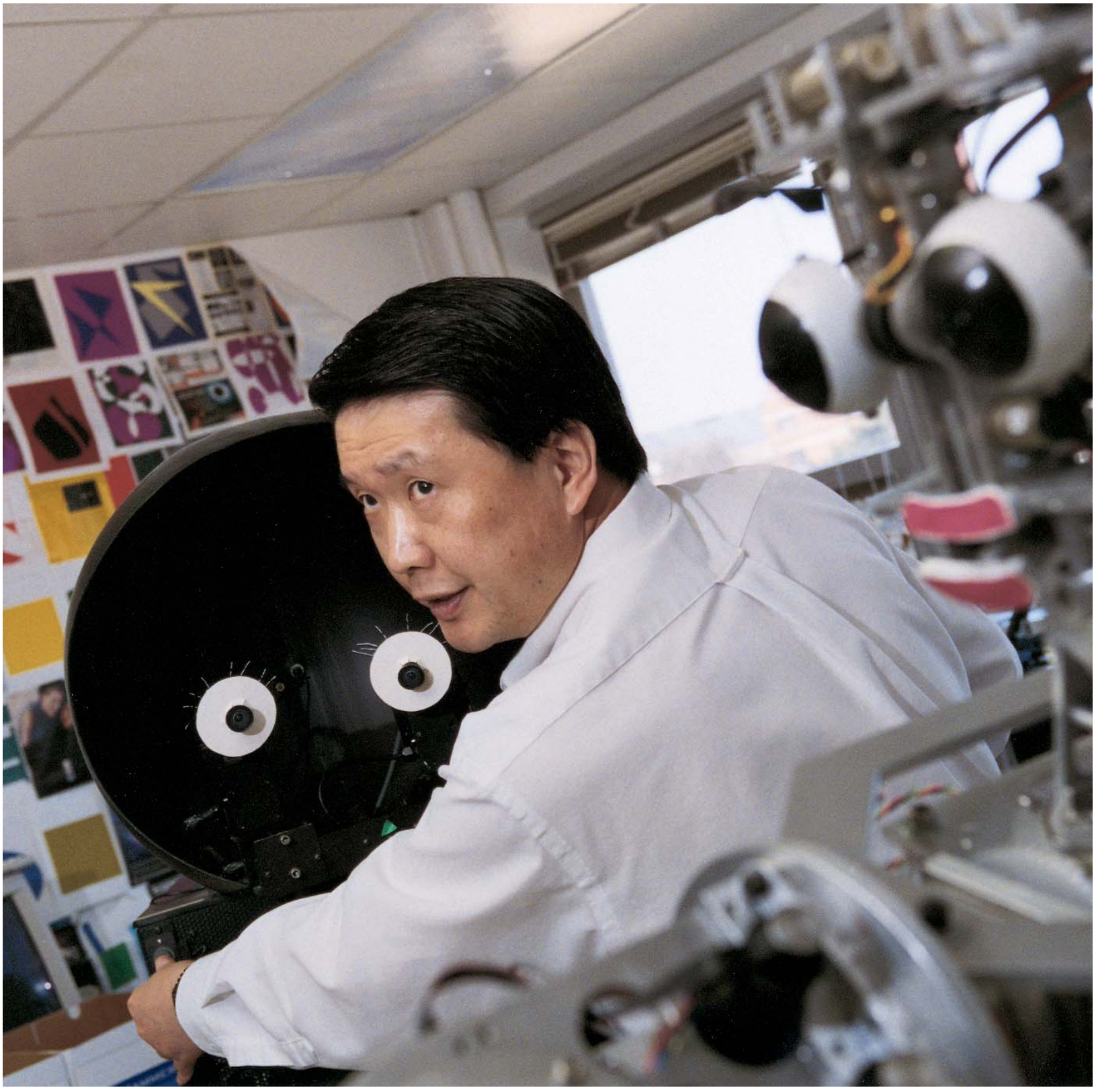
Family portrait: Juyang Weng focuses his attention on SAIL, his first "developmental" robot, while younger brother Dav looks on.



DEMO

TEACHABLE ROBOTS

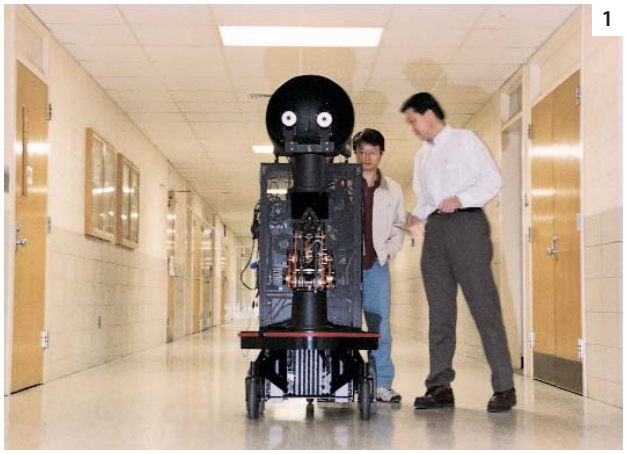
Want the perfect mechanical assistant? Forget about programming, says Juyang Weng. Just take these robots to school.

Like any proud parent, Michigan State University computer scientist Juyang Weng has a lot to say about what sets his little ones apart from their peers. Traditional robots, he explains, must be specially programmed for new tasks. And you just can't teach them much. Sure, they can acquire data—but only within narrowly defined parameters set ahead of time by their programmers. "But human learning is not like that," Weng says. "Human learning is real-time, online, on the fly." And that kind of learning, Weng says, is essential if you want a machine to be able to cope with the unexpected—unpredictable terrain, new people or objects, noisy settings—which will surely confront robotic household assistants and military machines alike.

In 1994, Weng and his team set out to build a robot with a capacity for learning like that of a human baby. They came up with a black, moon-faced machine named SAIL, short for Self-Organizing Autonomous Incremental Learner, endowed with what Weng calls a "developmental program"—a program that imparts attributes such as curiosity. Then SAIL was "born." "'Birth' means that the robot starts to interact with the real world, just like a baby interacts with his doctors, his father, his mother," Weng explains. "These interactions make the robot gain a sense of the outside world." Through such exploration, SAIL has learned tasks like navigation, identifying and sorting objects, even some speech. And he now has a younger—though physically more sophisticated—sibling, Dav. Weng introduced his robotic family to *Technology Review* senior editor Rebecca Zacks.

PHOTOGRAPHS BY CHRIS LAKE

1-2. Just like a human child, a developmental robot such as SAIL needs good teachers. To give SAIL a lesson in navigation, for example, Weng and graduate student Xiao Huang walk the robot through the halls of Michigan State's Engineering Building. SAIL's two camera eyes survey the scene, while his human teachers push force sensors on the back of his shoulders to indicate when he should move left or right to turn corners and avoid passersby. Eventually, SAIL gets the idea and can navigate the hallway on his own. "Basically it's like a kid on a bicycle," says Weng. "You hold onto it to practice, and you let it go when it's more skillful."



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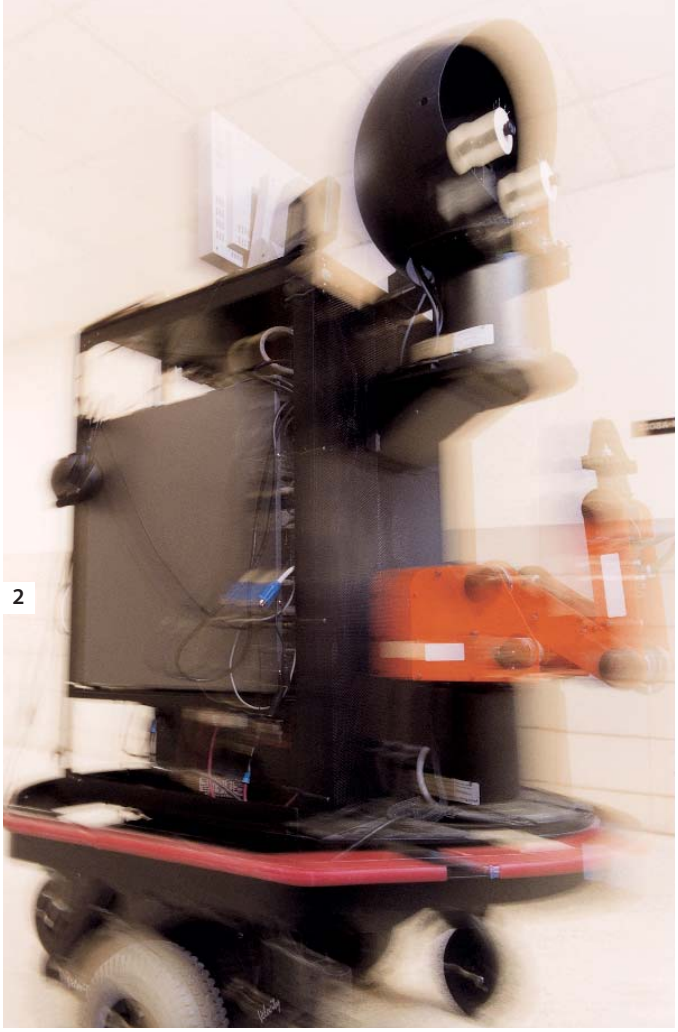

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3-4. Who says Barbie isn't an educational toy? Weng uses her, along with a host of other dolls and stuffed animals, to teach SAIL to recognize objects. SAIL holds the doll using its orange arm and rotates it to get a look from all different angles. Weng presses small switches on the robot's arm that tell SAIL that the name of this toy is "Barbie," and that its size is small. After just three or four practice runs with a new toy, Weng says, SAIL can tell you the toy's name on its own, using a voice synthesizer to speak it aloud. What's more, the robot can sort the toys he's familiar with by size, dropping them into boxes labeled "small" and "large."

5. SAIL's intellect has grown a lot through years of such training exercises, but the robot's body—with its simple sensors and restricted mobility—limits what it can ultimately do. So last year, Weng and his crew put together a new sibling for SAIL, a shinier, more humanoid creature called Dav, pronounced "Dave." Weng explains the name: "It's a kind of a variant form of the word 'development.' We just changed it a little bit, from *e* to *a*." Dav has camera eyes that can pan, microphones for ears, and lips and eyebrows for making basic facial expressions. His multijointed arms and hands are equipped with sensors that register position, force, motion, and other variables. Weng bends down to point out the equipment that drives the machine's wheels. "Each wheel is handled by two motors," he explains, "and the four wheels are synchronized so they don't fight each other."

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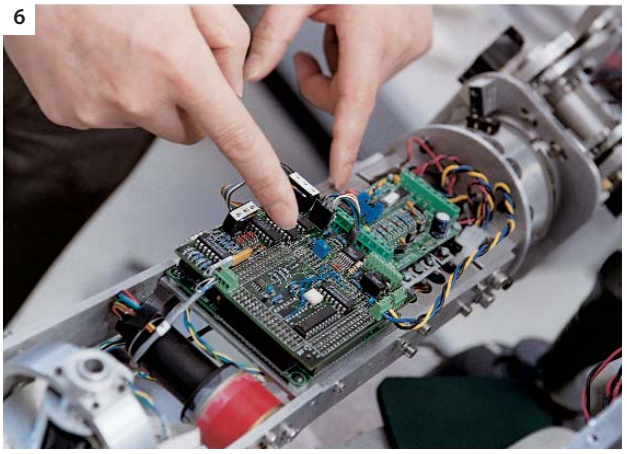

6. Loading Dav up with sensors, effectors, and electronics presented a challenge, Weng says: dealing with all the wires. If each device were connected by its own wire to the central "brain" in Dav's abdomen, he explains, pointing out a sensor in the robot's arm, "you would have a few hundred wires running through the elbow or through the wrist." That would be an unacceptable impediment to the robot's flexibility, so the researchers chose to network all of Dav's embedded devices to save both space and weight. Even with such tricks, Dav weighs in at 242 kilograms.

Despite his size and his mechanical sophistication, Dav is still a baby. Soon, he will start down the trail blazed by his brother SAIL, learning to walk, talk, and eventually, perhaps, understand the world around him to a degree no other robot has achieved before. And as Weng perches between his two offspring, one has to wonder if they both might learn a little bit about sibling rivalry.