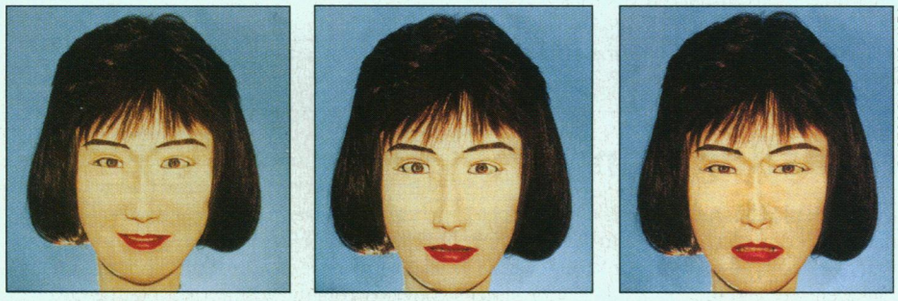
ROBOTICS

Putting a Human Face on a New Breed of Robot

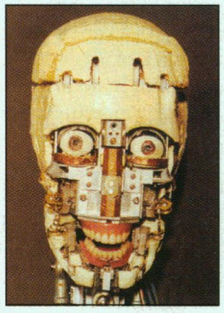
TOKYO—From the robot C-3PO of *Star Wars* fame to the android Data from the television series *Star Trek: The Next Generation*, people have dreamed of computers with human faces and feelings. Although getting machines to feel emotions is still out of reach, researchers at the Science University of Tokyo are developing a robot that can do the next best thing: recognize and display facial expressions.

Slightly larger than the average human head, the "face robot" is part of a burgeoning effort to improve communications between humans and machines, whether in a manufacturing plant, theme park, or other work environment. But the face robot fills a crucial void in the effort, says one of its creators, computer scientist Fumio Hara. Conventional studies of man-machine communications, he says, overlook the fact that for humans the face "is the most important instrument for transferring a message."



PHOTOS BY: FUMIO HARA

Revealing glances. Hara and Kobayashi's robot, displaying happy *(left)*, normal *(center)*, and disgusted *(right)* expressions. The machine behind the face *(below, right)*.



The Japanese government seems to concur that there is a research gap: Earlier this year it gave Hara a $3 million, 5-year grant to fund the face robot project, now in high gear in his sprawling, 30-person lab in Science University's mechanical engineering department. News of Hara's crude prototype is just beginning to trickle west. "From what I've seen, it's a very interesting, very challenging project," says Homayoon Kazerooni of the mechanical engineering department at the University of California, Berkeley.

Hara and his collaborator Hiroshi Kobayashi trace the project's roots to the 1970s, when a series of explosions in Japanese chemical plants due to human error prompted psychologists to explore possible connections between facial expressions and communications on the job. Those concerns became more urgent in the 1980s, says Hara, when Japanese scientists began talking seriously about building autonomous robots to cooperate with workers in industrial settings. To help bridge the gap between humans and cyborg co-workers, he and his colleagues dreamed up the idea of a face robot.

The resulting first-generation robot looks much like a Japanese female mannequin, with a rubberized face and a shock of natural black hair. But mounted in the head's aluminum frame is a charge-coupled device camera that peers out through the robot's plastic left eye, scanning brightness values across a person's face. To recognize an expression, a computer hooked up to the robot compares the distances between darker areas corresponding to the eyes, mouth, nose, and eyebrows to default values for a composite poker face. The computer can determine a displayed expression within 60 milliseconds by comparing the differences in position of facial features against stored templates for various expressions.

When Hara's team put the face robot through its paces by having it identify the facial expressions of 15 volunteer students, the robot performed remarkably well. Overall, it correctly identified expressions of happiness, surprise, sadness, anger, fear, and disgust 85% of the time. In a study the group presented at a workshop last year, human subjects correctly identified the same six expressions worn by professional Japanese actors 87% of the time. The most troublesome expression for the face robot was disgust, which it misconstrued as anger four times out of 10. However, says Hara, human subjects made the same mistake almost as frequently.

The face robot can also dish out what it sees. "A machine doesn't need to express feeling, but a person needs to feel some kind of warmth or kindness from it," says Hara. The robot has 18 air pressure–driven microactuators—gears that can change the position of its facial features. Displaying an expression requires activating a distinct combination of microactuators. Hara borrowed from social psychologists a schema for coordinating the movement of the actuators. According to studies in the late 1970s led by Paul Ekman of the University of California, San Francisco, the movement of facial muscles is divided into 44 "action units," each of which corresponds to a visible change in facial expression, such as a wrinkling nose or pouting lips. A combination of microactuators carrying out the action units produces each of the robot's expressions. Three action units go into making the robot's sad face, for example: raising the eyebrows' inner ends, lowering the eyebrows' middle portions, and pulling out the corners of the lips.

The robot's expressions mimic the human equivalents fairly closely. Hara showed photos of the robot with its six expressions to 30 students, who were asked to identify each expression. The students correctly identified them 83% of the time. The robot's Achilles' heel was fear, which the students could recognize only half the time. Part of the problem with identifying fear may be that it is more complicated to show than other expressions. Fear takes the movement of eight action units compared to an average of four action units for the other expressions. Hara is working to fine-tune the robot's fear expression as well as develop faster microactuators for better real-time facial displays.

The next big step will be giving the face robot a voice. Indeed, one of Hara's doctoral students has begun building a "mouth robot"—microactuators set behind dentures and silicone-rubber lips that will simulate the facial movements of speech, which could be provided by a synthesized voice. Eventually, Hara says, his team could unite the face and mouth robots in a second-generation robot which might also be endowed with simulated breathing and tongue motion.

A breathing and talking robot that displays expressions could be useful for a range of applications, says Hara, from serving as a warning system on a manufacturing plant's control panel to functioning as a "tutor" attached to a CD-ROM drive. When such a robot debuts, perhaps a decade down the road, Data and other sci-fi machines will have a real-world rival.

–Richard Stone