The Finishing Touch

Robots may lend a hand in the making of Steinway pianos

By IVAN AMATO

Hands, hundreds of them, bring each Steinway piano into the world by fashioning, assembling and adjusting more than 12,000 parts. Hands from the likes of Horowitz and Ashkenazy have tapped the acoustic magic crafted into these instruments. And every day in concert halls around the world, thousands of hands applaud such performances.

Within the year, Steinway executives will learn if a robotic hand, under development at Columbia University, will prove skillful and sensitive enough to hire. If so, Steinway & Sons piano manufacturers in Long Island City, N.Y., will gently enter a new era marked by a touch of automation.

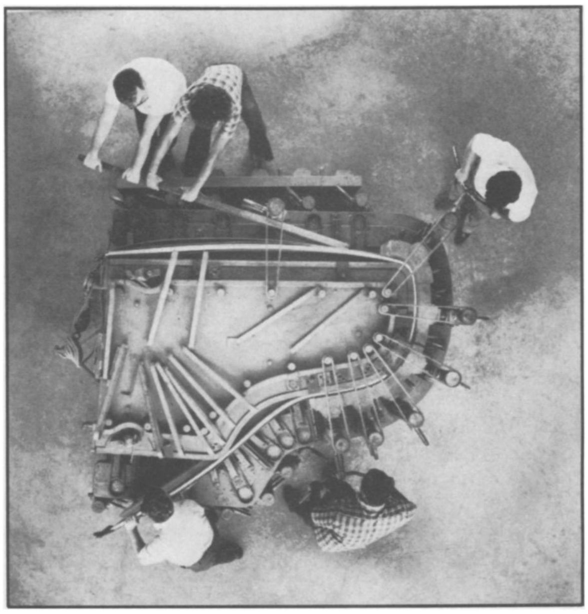
Not that the piano maker is a stranger to innovation. "We like to think that Steinway was very much on the leading edge of technology during the development of the modern piano back in the late 1800s," says Gary Conte, Steinway's director of engineering. The Steinway he refers to is C.F. Theodore, son of Henry, who came to Manhattan from Germany in 1850 to found the now-famous piano factory. A hundred years ago C.F. Theodore keyed into the latest acoustical research of physicist Hermann von Helmholtz for his own patented piano designs. He also invented the one-piece piano rim made of nearly 20 laminations of veneer, and the mechanical apparatus to make the rims. "We look at the robotic project as continuing in that old tradition of innovation," Conte says.

Mechanical engineer Frederick F. Ling, head of Columbia University's Productivity Center, forged the Columbia/Steinway connection last spring. He and Daniel Koenig, Steinway's vice president of manufacturing, agreed that automating the piano-cabinet finishing process would be a suitably conservative place to start, since it has nothing to do with the piano's sound.

Designing and building the robot rubber is the charge of Moshe Shoham, a mechanical engineer at Columbia University and principal investigator on the project. By assembling existing robotic components in new ways and using novel computer control tactics, Shoham hopes to build a tireless, boredom-immune robot that finishes piano cases as finely as an experienced human worker but in far less time.

The process by which a Steinway piano case gets its ultrasmooth, low-gloss finish is grueling. Using a 30-pound rubbing machine, sandpaper on wood blocks, steel wool, cotton wool, rubbing oil and mineral spirits, a human finisher – called a "rubber" – spends an entire day muscling a perfect finish on just one lacquer-coated grand piano. "It looks like a sweat shop from 100 years ago," says Shoham.

Replacing humans with robot rubbers would eliminate a boring, messy and labor-intensive job, and should make the finishes more consistent, Koenig says. Besides, Ling adds, finding people willing to stick with these jobs is getting tougher.



Steinway & Sons

Steinway workers forming a one-piece piano rim.

Building the robot also won't be easy, Shoham says. For one, the robot must adapt to the subtle variations of each hand-fashioned piano. It must be dexterous enough to reach every part of each piano case, and sensitive enough to "know" how much pressure it is applying to the flat, curved and oddly shaped surfaces. On some piano models, the outermost veneer is about the same thickness as an issue of SCIENCE NEWS. "You have to know that you're not going to sand right through it," Shoham says.

The rubbing procedure of this Adam of future robot rubbers will resemble what human workers do. Last summer, Shoham and former graduate student Glenn Pereira recorded the workers' stroking patterns and measured the forces they exert on the piano surfaces. Shoham thinks their observations suggest that two robots – one for coarser work using the heavy rubbing machine, the other for finer work using wood blocks – may ultimately be the way to go. For now, Shoham is incorporating the data into software that will control a single prototype.

The robot essentially will be an arm equipped with a fast-acting and sensitive "hand," or actuator, that can grasp and manipulate the same tools the human rubbers use. The pianos will rotate on a turntable, giving the arm access to every square inch of their cases. The robot must properly position the rubbing and sanding tools and judge how much force to apply at each spot on the case. "It needs constant sensory feedback" from a force sensor, Shoham remarks. "A majority of the industrial robots employ purely position control schemes," he notes. Good, reliable force control is a rare robotic skill, he adds.

Most current robots cannot respond fast enough to the force sensor's flow of information. "It's difficult to get a high-quality surface finish" with such robots, Shoham says. "We will develop a new control strategy for defining appropriate actions and analyzing sensor signals." The robot arm Shoham is using comes with its own computer controller that guides the arm's grosser movements. Using feedback information from the force sensor, another computer will control the finer movements of the fast actuator and will relay signals to the robot controller so it can carry out any necessary compensatory movements of the arm. The first tests of the system are still a few months away, Shoham says. "In six months we should know if it [a robotic rubber] is possible," he says.

Although Shoham, Koenig and others expect to put the first-generation robot rubber on the job in a year or so, nagging questions will become more important later on. Changing a piece of sandpaper on a wooden block, for example, is a cinch for people but more like a Herculean task for a robot. Also, the rubbing machine's vibrations could "confuse" the force sensor, causing the robot to apply improper forces to the piano case. Circumventing such problems might involve designing robot-friendly finishing tools, Shoham says.

Each of the 3,000 pianos Steinway completes in a year spends almost two years in the factory. The instruments cost plenty, too — over $8,000 for the least expensive upright and more than $53,000 for a special-order Walnut Concert Grand. Automated manufacturing makes many foreign imports less expensive, says Ling. For example, in a span of 2½ years, Yamaha — once known mostly for its motorcycles — mass produces about as many pianos as Steinway has built in its entire 135 years of existence as a U.S. company — about 500,000.

If Shoham's robot rubber produces human-hand-quality finishes while trimming production time and cost, Koenig says he will look to hire other robotic hands. He adds, however, that human touch will always be the most essential ingredient of the Steinway sound. □

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