The whole house machine

This is why people think robotics are the future

In a sunny laboratory at the University of Southern California, a robotically controlled nozzle squeezes a ribbon of concrete onto a wooden plank. Every two minutes and 14 seconds, the nozzle completes a circuit, topping the previous ribbon with a fresh one. Thus a five-foot-long wall rises—a wall built without human intervention.

The wall is humble but portentous. "If you can build a wall, you can build a house," says Behrokh Khoshnevis, an engineering professor, as he watches the gray mixture spurt out in neat courses from what he calls a contour crafter, a machine about eight feet tall and six feet wide. If all goes as planned, Khoshnevis will use a larger, more advanced version of the device later this year to erect the first robotically constructed house in just one day.

Khoshnevis believes his contour crafter will revolutionize building construction.

By Brad Lemley  Photography by Sian Kennedy
ABOVE: With a soft whir, the contour crater’s head lays down inch-high extrusions of viscous concrete, one atop another, as a pie-shaped trowel smooths the surface. The head moves at 5 inches per second, which would create a 2,000-square-foot house in 24 hours. (Photo: The prototype machine, which cost $20,000 to build, is now at NASA’s Marshall Space Flight Center, where engineers will determine if the technology can be used to erect moon buildings out of lunar dust.)
dragging it into the digital age. Today, des-

pite the advent of tech tools like power
saws, mechanized cranes, and pneumati-
c传奇, construction is essentially the same
tiring, gritty job it has been for 20,000
years. Workers still have to cut, grasp, hoist,
place, and fasten materials, which is why
labor accounts for about half of a build-
ing's cost. The process is dangerous, slow,
and wasteful. More than 400,000 Ameri-
can construction workers are injured each
year, and a typical American house takes
at least six months to complete, generat-
ing about four tons of waste.

Khoshinev, 54, a prolific inventor who
emigrated from Iran in 1974 and holds
patents in fields ranging from optics to
robotics, decided there had to be a better
way while troweling plaster cracks in his
living room following the 1994 North-
ridge, California, earthquake. "It occurred
to me that a trowel, a very simple tool that
has been used for ages, can actually cre-
ate nice, smooth surfaces. In manufact-
uring, that is always what you are after.
Yet not a single automated manufactur-
ing process used trowels," he says.

To prove automated troweling could
work, he invented a small-scale machine
for making objects no more than 30 inches
across. Guided by input from a computer-
assisted-design program, the little contour
crafter has a nozzle that navigates on three
axes and squeezes out ceramic clay like
toothpaste from a tube. A pair of trowel-
like fins smooth the top and side surfaces
as the layers stack up, yielding cubes, boxes,
bowls, domes, cones, or other shapes spec-
ified by the software. The device is similar
to rapid prototype machines, which have
been used for about 15 years to print out
dimensional plastic models, but the trowels
"allowed a new degree of control on the
exterior surfaces," says Khoshinev.

It worked well on this small scale, so
the engineer said to himself, "Why not use
cement and make a whole house?"

Funded by a National Science Founda-
tion grant and aided by engineering grad-
uate student Doool Hwang, Khoshinev
designed and built a wall-making machine.
"I gave myself three years to build it, but
it took only 16 months," says Hwang. The
chunky machine uses two parts standard
cement mix ("You can get it right off the
You could set it up on a site to build one house or a whole row of houses.

"You could set it up on a site to build one house or a whole row of houses," says Khosnevics. He has even designed a contour crafter that climbs, allowing the construction of skyscrapers.

As smart as the idea of contour crafting seems to be, houses require more than good engineering. They will not be popular if they resemble concrete bunkers more than elegant, graceful homes. Khosnevics points out that the exterior trowel could be followed by a rolling die that prints a brick, shingle, or clapboard pattern in the wet concrete, while the interior could be painted using ink-jet technology in any color, or even in wallpaper patterns. The concrete itself could be of varying types, including versions that resemble adobe or plaster.

With more complex nozzle architectures, the machine could make buildings that are not just cheaper and quicker to build but far safer too. Today, for example, making a house earthquakeproof is material intensive, expensive, and inelegant. But a contour-crafted building "can be strengthened in a smart way" says Khosnevics. "The reinforcement steel and even the chemical composition and thickness of the walls could be changed on the fly, with more added precisely where it is needed." Some building professionals are enthusiastic. Greg Lynn, a Los Angeles architect who specializes in buildings with curvilinear, organic shapes, was pleased to discover that "this machine doesn't care if it is doing curves or lines. Living in a rectangle becomes an option, not mandatory." If a whole-house machine existed today, Lynn says, "I'd be using it right now."

"It's exciting," says Dennis Shelden, chief technology officer of Gehry Technologies, a Los Angeles building technology research and development company. "This represents the next step forward. But he cautions that there may be structural issues. "We need to take a close look at how good the bond is between the layers."

Khosnevics is confident that won't be a problem: "The extruded layers can serve as form walls for a filling layer of structural material." Because that filling layer would be a monolithic slab of concrete, "it will be plenty strong," he says.

Even NASA seems to be interested. Khosnevics recently shipped a prototype wall builder to engineers at the Marshall Space Flight Center. They want to find out if contour-crafting technology could erect buildings on the moon from lunar dust.

Here on Earth, what about all those construction workers who would suddenly be out of a job? "This concern is nothing new," says Khosnevics. "When the automobile came along, people said, 'What will happen to all of those horse-carrriage drivers?' But technology that makes sense typically brings dramatic social changes for the good. This is no different."

Khosnevics is inspired by the technology's potential to build dignified low-income housing. "A billion people today do not have adequate shelter," he says. Using soil dug from the building site and stabilized with cement, the contour crafter could erect inexpensive dwellings customized to a family's needs.

"This technology is like a rock that we have rolled to the top of a cliff," Khosnevics says. "Just one little push, and the idea will roll along on its own."