

### The House That Behrokh Wants To Build

Can robotics 'print' out a four-bedroom house?

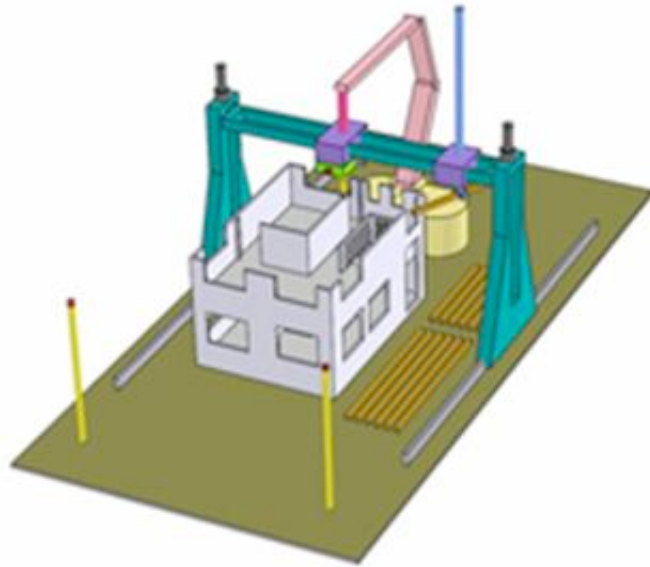
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# LAWEEKLY

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On the computer screen in front of me, a house is going up. Before my eyes the building materializes rapidly as layer by layer of concrete is laid down, each stratum squeezed out of a huge nozzle as if from a gigantic toothpaste tube. This is not the construction of an actual house, not yet anyway; what I am watching is an animation of the way in which houses of the future may be built. Known as contour crafting, the process is the brainchild of USC engineering professor Behrokh Khoshnevis, who believes his technology will make it possible to build a house from foundation to roof in less than 24 hours: "Our goal," says Khoshnevis, "is to be able to completely construct a one-story, 2,000-square-foot home on-site in one day without using human hands."

In the age of instant everything, the cake-mix house was perhaps inevitable: Just add concrete powder and press the start key. With Khoshnevis' system, the whole building process would be automated using special robotic equipment transported to the site. Entire enclaves could be built in weeks, and unlike the cookie-cutter conformity of most tract housing, each home could be a unique design. Though the process is robotic, Khoshnevis sees his technology as a means by which individually tailored houses could be made practical and affordable on a wide social scale. The machines he has designed can create any



kind of three-dimensional structure, from simple cubes and boxes to domes, cylinders, cones, cones coming out of boxes, domes perched on top of cylinders, plus completely irregular forms and complex compound curves. "Architects love this technology," Khoshnevis declares; structures that have never been possible before, or were prohibitively expensive, suddenly become as easy as rectilinear slabs. Khoshnevis is currently working with a UC San Diego team that has proposed that NASA use contour crafting for lunar constructions.

"Any sufficiently advanced technology is indistinguishable from magic," Arthur C. Clarke once remarked. One of the goals of magicians everywhere is to manifest objects out of nothingness, and Khoshnevis' conception of the instant house is an extension of a technology that does exactly that. Known as rapid prototyping, or R.P. for short, it is one of the truly magical innovations of the modern scientific era. As the name implies, R.P. systems are generally used to fabricate three-dimensional models or prototypes — they are widely used in the auto and aerospace industries. Initially a computer model of the object is created — a digital version of the Platonic ideal — then, under computer control, a physical version of this form is built up gradually, layer by layer. There are various methods for achieving this almost miraculous materialization; Khoshnevis is the inventor of a particular version with the alchemical-sounding name of Selective Inhibition of Sintering.

The idea of applying an R.P. philosophy to houses came to Khoshnevis one day while he was patching up some plaster in his living room. "It occurred to me," he says, "that in car manufacturing we build much more complicated structures all the time. All we'd have to do is to scale up the existing technology." Scale is the critical issue here: Car parts might be complex, but typically they can be measured in inches, a couple of feet at most.

Khoshnevis' major challenge has been working out ways to practically implement a large-scale system. Later this year he'll be testing his first scaled-up version using grant money provided by the National Science Foundation. That test structure will be just a simple straight wall, but Khoshnevis is talking to the NSF about a further grant of \$5.5 million to put together a full-on production system capable of building an entire house. He even has a site in mind, donated by the Pasadena-based California Institute of Earth Art, which hopes to see this test house implemented in adobe.

Khoshnevis has already built a small-scale version of his system that can turn out objects from a few inches in diameter to about a foot across. In his office at USC's Information Sciences Institute, in Marina del Rey, a dozen of these forms sit on a shelf beneath a window that opens out to a spectacular view of the harbor. I pick up a tapered cylindrical form, imagining it in my mind's eye as a small tower. It feels surprisingly smooth — I had expected a rougher surface. Smoothness has been one of the significant technical hurdles. Khoshnevis notes the precision of his manufacturing tolerances and points out that most people like their walls pretty even.

On another shelf rest a couple of objects that are clearly proofs-of-concept for constructing curved vertical walls. Fluid and elegant, they would be equally suited to a high-desert landscape or a futuristic city. I ask Khoshnevis if it is really conceivable that we could build such structures on a suburban lot, and he assures me that in principle this is child's play. For decades "We've been doing much more complex things with robotics," he says. "This is all very simple assembly."

In auto factories the machines are fixed in place; in order to build houses the equipment would have to be transported to the site. Khoshnevis' animation shows what such a setup might look like. Two large rails are installed along the sides of the lot, a gigantic movable gantry atop them, to which is attached the nozzle machinery. Beside the rails stands a tank to hold the building material — concrete or some kind of composite. Khoshnevis punches the start key, and the gantry begins to ride up and down the rails while the nozzle emits a steady stream of material in a precise pattern predetermined by the architect's design. In a typical rapid prototyping system, each layer is a fraction of a millimeter thick; Khoshnevis' layers are some 2 to 3 inches deep.

In the physics-free space of computer simulation, a house materializes in five minutes flat. Another name for rapid prototyping is "object printing," and, in effect, Khoshnevis is suggesting that he could print a house. The gantry system with its concrete-spouting nozzle is in essence just a heavy-duty version of an ink-jet printer. Khoshnevis' team have also worked out a fully automated system for putting in the pipes and the electrical conduits; they could even automate the painting, literally printing colors and patterns directly onto the walls. About the only thing left to do manually is to grade the lot, prepare the foundations, and put in the windows and doors.

But a question remains: Is home building something that should be automated? Khoshnevis believes the answer is unequivocally yes. He notes that skilled construction workers are increasingly in short supply and that each year more than half a million people are injured on construction sites. Moreover, with traditional building methods, material wastage is enormous — 3 to 7 tons is typical for a suburban house. Khoshnevis claims that his technology would cut waste, reduce accidents and save money; he estimates a cost saving of at least 50 percent. It's hard to imagine construction unions signing on to such a project, and Khoshnevis certainly expects union opposition. But as he points out, we are moving toward a society in which almost everything is fabricated by machines. Why should houses be different? "We have all this sophisticated technology and know-how," he says. "Why shouldn't we apply it to building?"

It's a startlingly simple question — one that will be far from simple to answer.