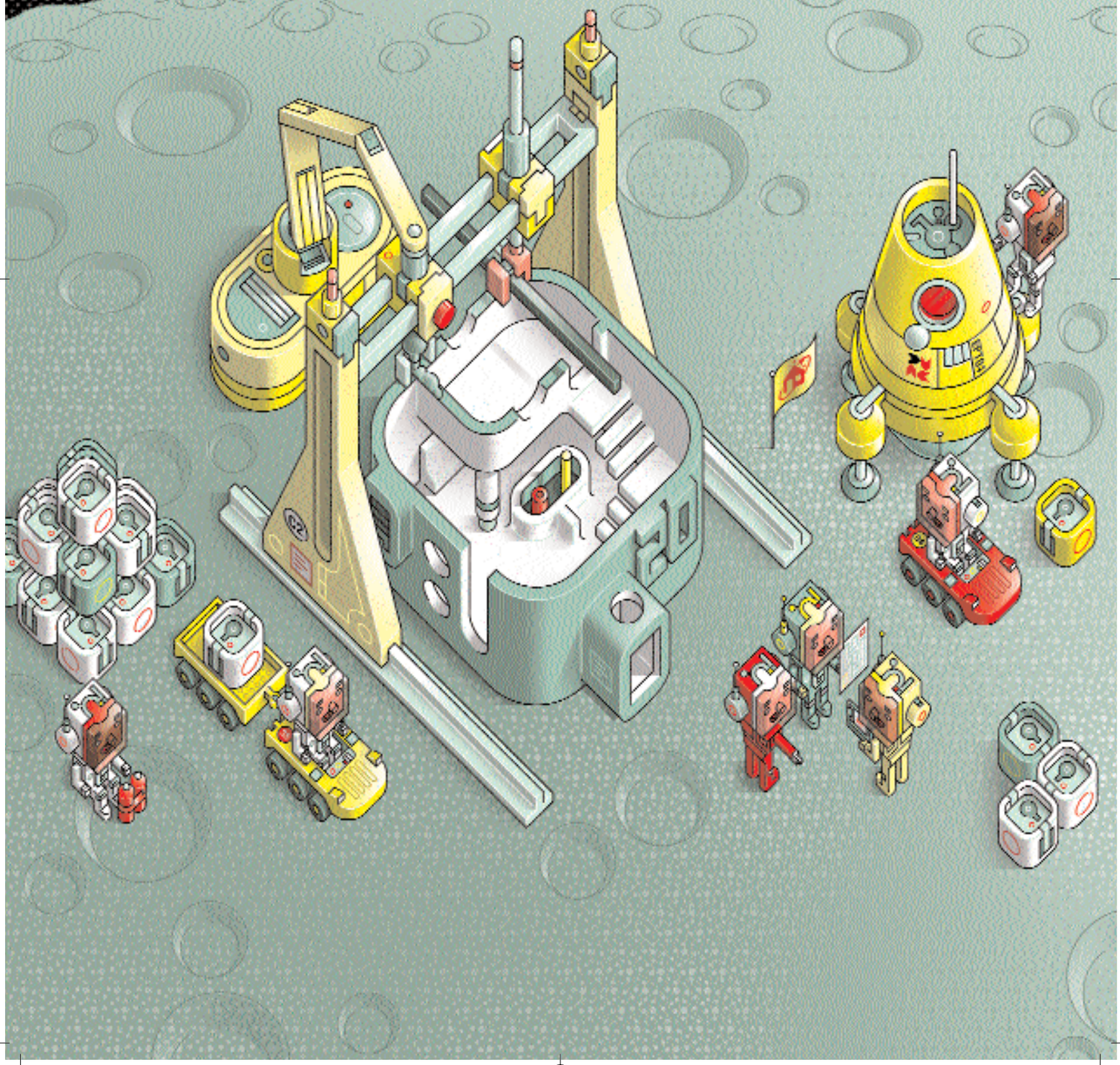
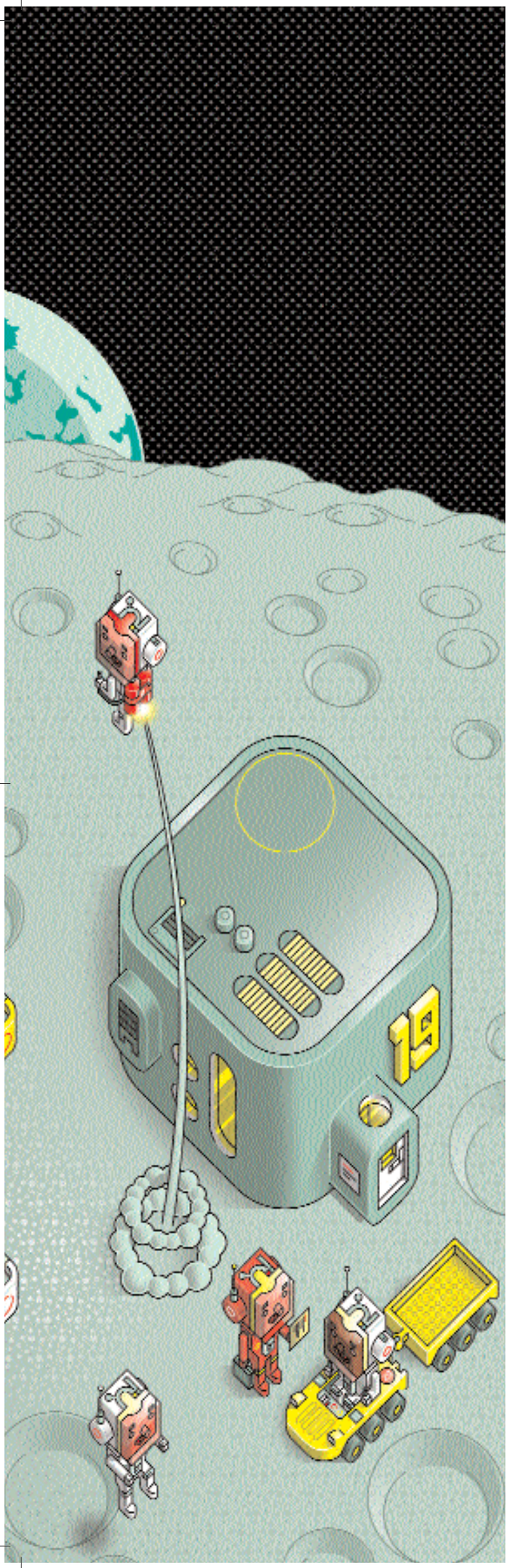
A GIANT LEAP FOR A BRICKIE

Behrokh Khoshnevis has seen the future of construction, and it involves robotic arms, multiple nozzles and buildings that can be put up in hours in either Basildon or the Sea of Serenity. The University of Southern California professor tells Thomas Lane about the technology that he believes will be commonplace in 15 years





LEE HASLER

IT IS THE YEAR 2015 AND TWO CONSTRUCTION PROJECTS ARE starting on site in two different places.

On the moon, a research station is being constructed by robots. On top of a gantry, in place of the usual lifting hoist, an automatic arm extends downwards over the station. At the end of this arm, a nozzle squirts a concrete-like material onto the half-built walls like a mechanical hand icing an implausibly large cake. At the same time, computer-controlled trowels shape and smooth the concrete so that it's flush with the wall below. The whole assembly moves back and forth to build up internal and external walls in layers. Further robotic arms are positioning services inside the building and lifting lintels onto the walls in order to make the roof. In just 24 hours, the house will be complete.

Meanwhile, back on Earth, the second project is getting under way on a small plot in Basildon, Essex. Here a small local contractor is building four homes using precisely the same method, but without the enormous blue-marbled bulk of the Earth hanging over his head.

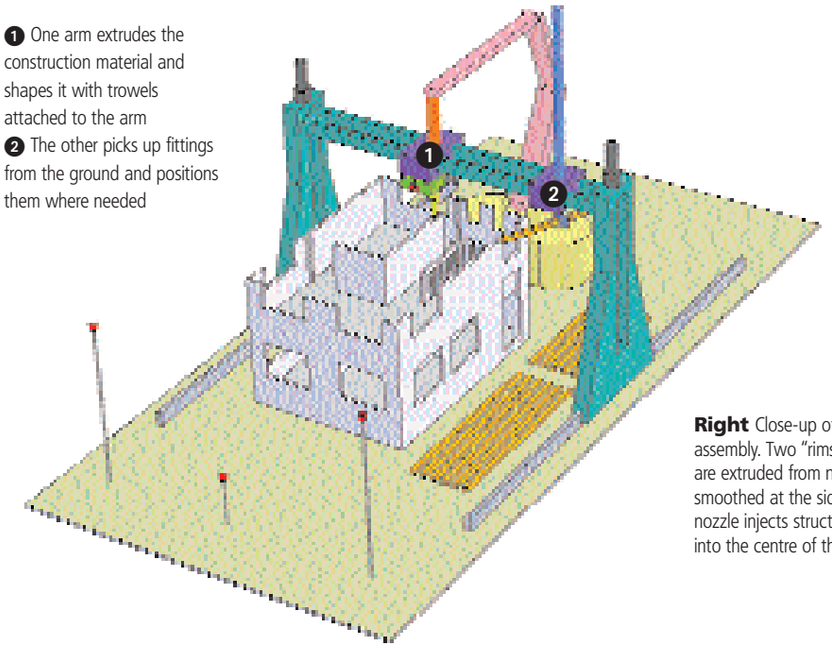
This is not a science-fiction writer's whimsy, by the way. It is a prototype construction method being developed by a team of researchers from the University of Southern California. Called "contour crafting", the method has already been used to build actual walls. The team reckons a single-storey home will be constructed next year, and that the system will be perfected within five years.

"It can build a single-storey 200 m^2 house in less than 24 hours," says professor Behrokh Khoshnevis, who pioneered the technique. "That includes all the plumbing and electrics and could include ▶

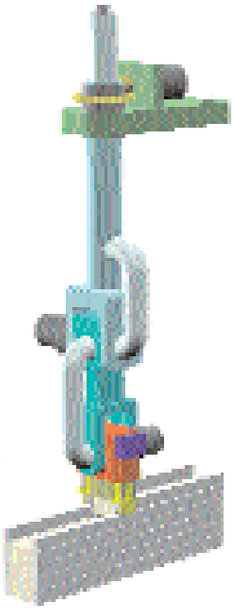
Developing the software

Much of the development work needed will focus on software as the whole system relies on sophisticated IT. "A lot of the software doesn't exist so we will have to develop it. What we are doing is considerably beyond what has been done before with robotics," says Paul Rosenbloom, a professor of computer science at the University of Southern California who is involved on the project.

Several types of software are needed for the system to work. Existing CAD programs used by architects and engineers can be used to design buildings. The next stage is to translate this into a computer language that can be understood by the contour crafting machine. Work will also focus on developing co-ordination software to enable multiple nozzles to work in harmony, and with the "pick-and-place" robotic arms. Furthermore, logistics software needs to be developed so the materials needed for the process are in the right place at the right time. The ultimate aim is that the system will engineer the structure once the architect has designed a building; it will be able to work out for itself how much and where materials are needed for the structure to work.



❶ One arm extrudes the construction material and shapes it with trowels attached to the arm
❷ The other picks up fittings from the ground and positions them where needed



Right Close-up of the nozzle assembly. Two "rims" of material are extruded from nozzles and smoothed at the sides. A third nozzle injects structural concrete into the centre of the wall

▶ painting it, too."

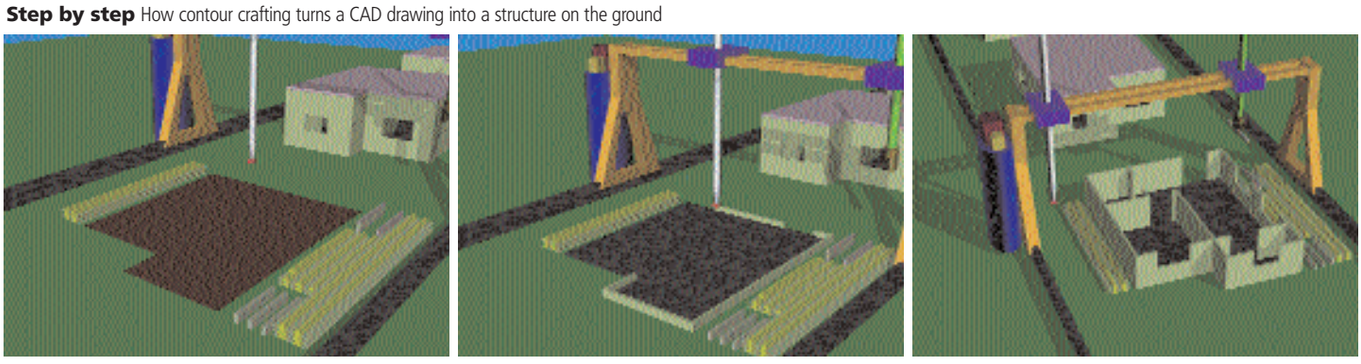
The method gives new meaning to the phrase "rethinking construction"; in fact, it could completely revolutionise the industry, thereby providing the perfect riposte to Dennis Lenard's recent criticism that site technology is stuck in the past.

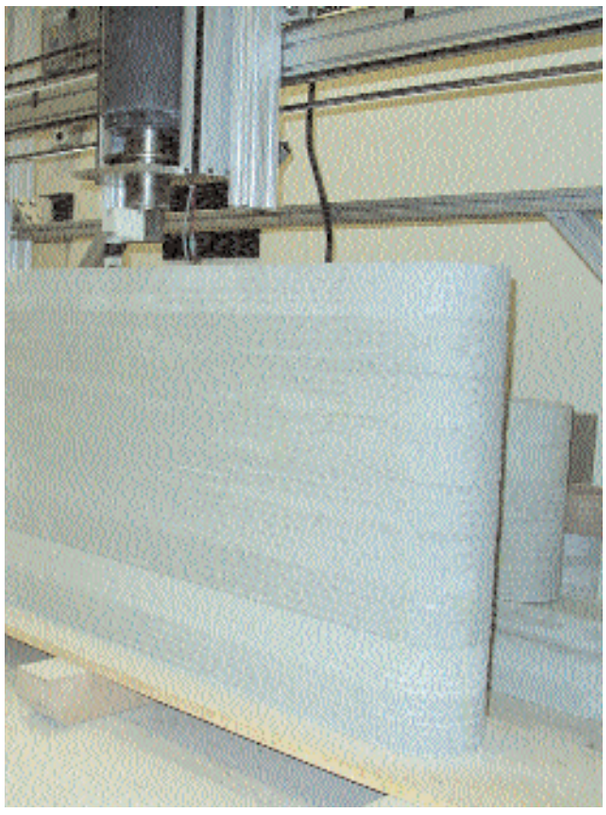
Such is its potential impact that it could wipe out the burgeoning off-site manufacturing industry in one fell swoop. Existing methods of off-site manufacture offer many advantages but essentially replicate site-based methods of construction in a controlled environment. This brilliantly thought-out method, on the other hand, starts from first principles, but takes them in a very different direction. "Whatever modern structures look like, they are built in the same labour-intensive way that has been used for hundreds of years," says Khoshnevis. "This results in inaccurate low-quality structures that cost five times more than necessary because they are all tailor-made. With this method we are entering a new era."

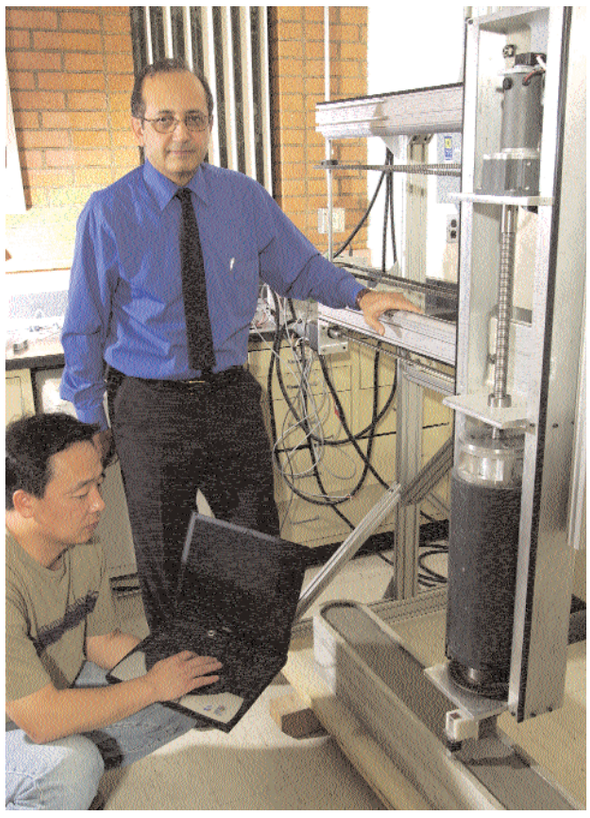
IT CAN BUILD A SINGLE-STOREY, 200 M^2 HOUSE IN LESS THAN 24 HOURS. THAT INCLUDES ALL THE PLUMBING AND ELECTRICS TOO

What is exciting about the technique is that it works directly from the architect's CAD drawing. This means that architects become programmers, and the robots can build almost anything from a drawing – the only limit is the architect's imagination. Initially, it is being developed to build quick housing, specifically

Step by step How contour crafting turns a CAD drawing into a structure on the ground







VOLKER CORELL

Above left Pure fantasy? The team have already built prototype walls and hope to build a whole house next year
Above right Professor Khoshnevis and the contour crafting machine

social housing and emergency shelters after earthquakes. It could also be used to construct taller buildings: the gantry would sit on tracks running up the sides of the building, and the robots would automatically add more tracks as the structure grew. Because the trowels shaping the construction material can be angled, the technique could also be used for constructing domes and arched structures.

Like many revolutionary ideas, this one germinated in a very unlikely way. "In 1994 there was an earthquake in Los Angeles and a big crack appeared in my wall," explains Khoshnevis. "While I was filling it, it occurred to me that the trowel was a very good tool as you can manipulate the material and get an excellent finish. At the same time, rapid prototyping processes were being developed, so I decided to combine the two to develop this idea. I started off with ceramics, then I thought: 'Why not build houses?'"

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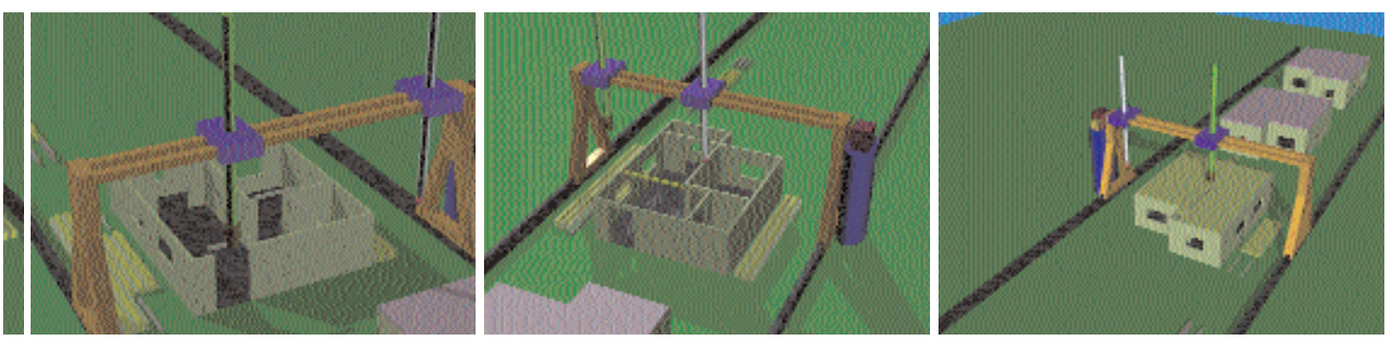
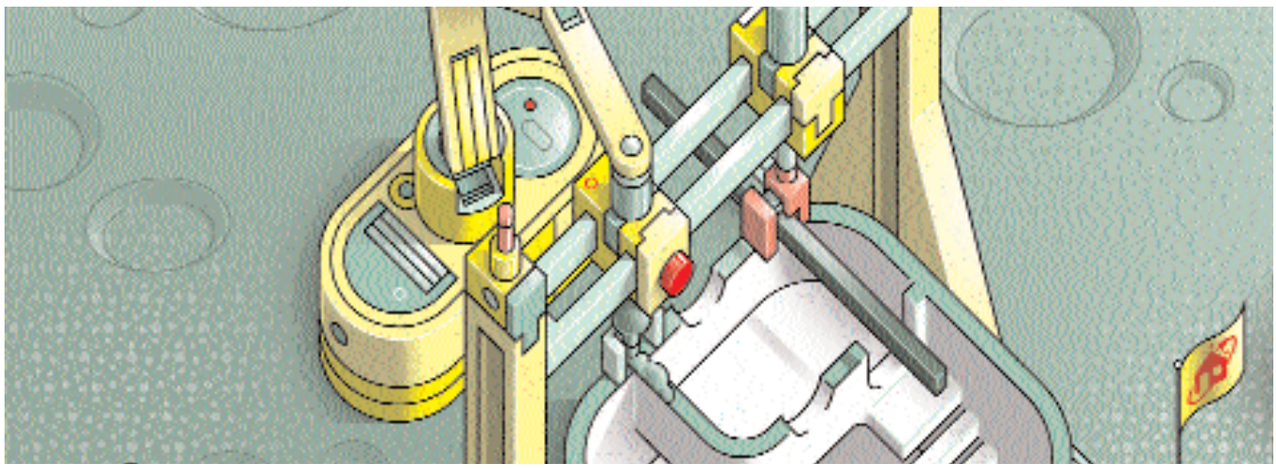
Rapid prototyping is a technology that creates physical prototypes automatically from designers' CAD drawings. Special software deconstructs the designer's drawings into very thin layers and then instructs a machine to deposit material in corresponding layers. Slowly, a physical model is constructed from those layers.

Contour crafting has taken this idea to a new level, as the full-scale prototype wall testifies. A wall can be built out of several materials at once because the head depositing the material ▶





IN 15 YEARS, THE MACHINES WILL COST £100,000-150,000 SO EVEN SMALL CONSTRUCTION COMPANIES WILL BE ABLE TO AFFORD THEM

▶ contains several nozzles. The prototype wall, for example, was built with a three-nozzle head that squirts two materials at either edge, and a third in the middle. These materials are deposited and smoothed in 25 mm layers. The materials are very thick and are forced out of the nozzle at high pressure so they don't slump into a puddle. A trowel on each side of the wall smoothes the outer material flush with the wall but leaves the inner edges rough to create a more effective bond for the material in the middle. With this system, plaster could be used on one side of the wall, render on the other and structural concrete in the middle.

The three-material prototype wall is just the beginning. There are potential pitfalls ahead, particularly with developing software solutions (see box, page 40), but the intention is for the technology to be capable of building a complete structure with cladding on the exterior and a painted interior. A fourth nozzle could extrude insulation into the wall structure with robotic arms putting the finishing touches to the outside of the wall. Further robotic arms could tile walls on the interior or put brick slips on the exterior face by spreading adhesive over the faces and applying the tiles. Interior faces could even be "wallpapered" using the same inkjet printer technology used for creating large advertising posters.

Ways of installing services and reinforcement as the walls are being built have already been worked out by the team. Voids are created inside walls by programming the deposition head to leave blank areas in the middle of the wall. Robotic arms place pipes inside the voids and weld sections together by using fittings pre-coated with solder. A heated, ring-shaped element clamps around the pipe and melts the solder. Prefabricated wiring sections will be plugged into each other inside the voids although sockets and other electrical fittings will still need to be installed manually. The reinforcement necessary for tall or complex structures would be robotically installed by screwing short metal sections into the protruding reinforcement, building up a layer of wall, adding another layer of reinforcement and so on.

The same system will also be used to build the roof by craning precast beams into position and robotically adding a waterproof layer over the top. Alternatively a domed or arched roof could be added. Khoshnevis says the system can also build the foundations, but as the technique used is currently being patented he could not divulge the details.

Khoshnevis' thoughts are already turning to less conventional structures. He has teamed up with German construction products giant Degussa to develop materials especially for the process. Materials could be varied throughout structures depending on what job they have to do. For example, the software could ensure that high-strength concrete is used at the base of buildings but lighter and weaker materials higher up. Walls of variable thickness could also be constructed. Sensors that measure heat, sound or stress could be embedded in the walls and could regulate temperatures or detect intruders.

The technology could be available to the general industry within 15 years, according to Khoshnevis. He envisages a lightweight, collapsible gantry system that can be unloaded and erected in 30 minutes, making it suitable for building individual homes. "In 15 years, the machines will cost £100,000-150,000 so even small construction companies will be able to afford them," he says.

Anyone tempted to dismiss this as fantasy should look at what happened to rapid prototyping machines. Not so long ago, this was a massively specialised and expensive business, but now machines resembling glorified office printers are available for £35,000, enabling designers to easily create physical models in-house.

The big question left for the notoriously conservative construction industry is: will it be brave enough to grab this opportunity, or will it end up sending construction workers to the moon armed with shovels and pickaxes?