

PARADIGM SHIFT

Dr Behrokh Khoshnevis of the University of Southern California has developed Contour Crafting, a technology capable of automating the process of construction. Niranján Mudholkar explores the myriad possibilities

Picture this: A design plan is fed to a computer-guided robotic machine. Then - like an inkjet printer that squirts ink and prints on paper, this robotic machine goes about spraying concrete in a thin layer that is smoothed, and shaped immediately by automated trowels near the nozzle. Thus, the design plan is materialised in the form of actual construction. That's right! In this 'virtual-meets-the-real' technology called Contour Crafting (CC), a robot will construct whole structures as well as sub-components like walls. The result? Immensely reduced labour costs, consistent and assured quality, decrease in on-site accidents and construction waste - and of course, huge savings in time. Not to forget - execution of the design plan without even a minute change. Welcome to the future! Here's a technology that could change the shape of things (well, almost literally) to come.

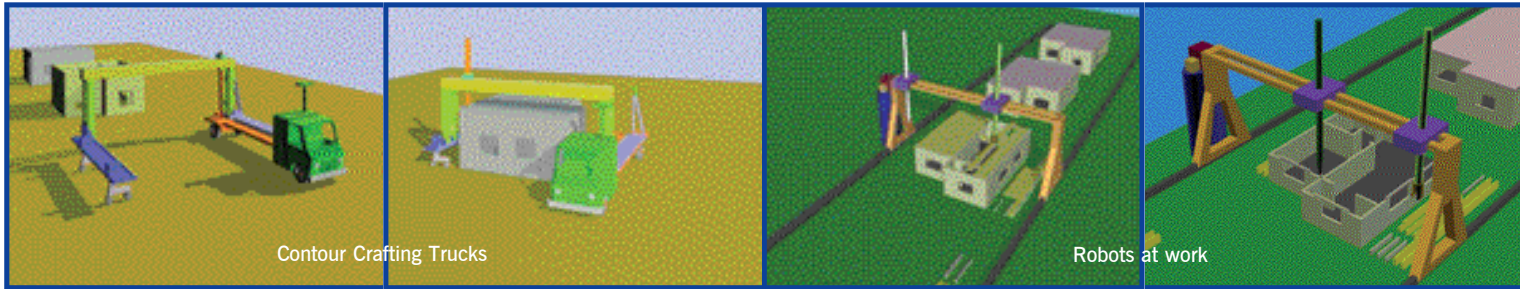
An amazing invention

Developed by Dr Behrokh Khoshnevis of the University of Southern California, Contour Crafting is a layered fabrication technology that is here to make automated construction a concrete reality. Basically, Contour Crafting is a process by which large-scale parts can be



About Dr Behrokh Khoshnevis

Behrokh Khoshnevis is a professor of Industrial & Systems Engineering and is the Director of the Center for Rapid Automated Fabrication Technologies (CRAFT) and Director of Manufacturing Engineering Graduate Program at USC. He is active in CAD/CAM, robotics and mechatronics related research projects that include the development of novel Solid Free Form, or Rapid Prototyping, processes (Contour Crafting and SIS), automated construction of civil structures, development of mechatronics systems for biomedical applications (like restorative dentistry, rehabilitation engineering and haptics devices for medical applications), and autonomous mobile and modular robots for assembly applications in space. He routinely conducts lectures and seminars on invention and technology development. He is a Fellow member of the Institute of Industrial Engineers, a Fellow member of the Society for Computer Simulation, and a Senior member of the Society of Manufacturing Engineering. He can be contacted at khoshnev@usc.edu



fabricated quickly in a layer-by-layer method. In fact, it could be the way buildings of the future will be built. Whether the need is for a single structure or an entire colony, Contour Crafting technology will render it possible through automated construction in a single run. Moreover - embedded in each house will be all the conduits for electrical, plumbing and air-conditioning. This remarkable construction technology will offer great scope for design variations too. Speed and superior surface finish would be the two major benefits of this technology over existing methods of construction. This would be possible through the combination of robotics, automated use of traditional tools and an innovative approach to building.

Various applications

The potential for this technology is immense in terms of the possible applications including (but not limited to) emergency shelters, low-income housing and even for building extra-terrestrial habitats.

Emergency housing: Millions of people are left homeless due to various natural disasters, wars and riots across the world. Though it takes very little time to destroy the homes, it can take months or years before the victims of these calamities are provided with permanent and in some cases even temporary houses. Basic necessities like food, water, medicines and clothing are made available by humanitarian organisations; but providing shelters is a daunting task as availability of transport and skilled labour immediately after a disaster is almost impossible. Under these circumstances, Contour Crafting technology can deliver strong dignified houses to the disaster victims very quickly. Contour Crafting can build a 2,000 sq ft house with all utilities for electrical and plumbing in less than 24 hours. This technology is adaptable and can use construction material available on site, thus eliminating the need to

transport materials long distances, saving the time and costs associated with transportation. Since Contour Crafting is an automated process, it allows the available labour to be utilised for relief and other important activities. As Dr Khoshnevis explains, "The technology is ideal for rapidly constructing dignified homes (not tents) for situations such as the recent earthquake affected areas in Pakistan - where roads and infrastructure are not sufficient for transporting pre-fabricated houses. A Contour Crafting machine may be transported and assembled (or air-lifted) to such locations and small pickup trucks or mules may be used to transport the material. A single machine may be able to construct a couple of nicely designed houses per day." Thus, Contour Crafting could save on time, costs as well as on valuable resources.

Low-income housing: Apart from natural and political catastrophes, another predicament that causes millions of people to live without proper shelters is poor economic condition. With an acute shortage of affordable housing, this problem is escalated further due to the rising population everywhere - particularly in developing countries of Asia, Africa and Latin America. At the same time, rapid and unplanned urbanisation too is adding to the woes. As a result, millions of people are forced to live under sub-standard conditions. We in India are rather very well acquainted with these problems and the subsequent troubles faced while implementing the rehabilitation programmes for the slum dwellers, like in the city of Mumbai.

Given the alarming status of the housing problem, conventional construction methods are bound to be inadequate in meeting these huge demands. Obviously, a new and effective method of construction like Contour Crafting technology will have to be considered for addressing the worldwide shortage of low-income or affordable housing. Dr Khoshnevis

hits the nail when he says, “A significant impact of the technology will be on the elimination of slum housing, because it will offer dignified construction at one fifth the current cost of construction. Currently, the population densities in the world are concentrated in poor areas where there is slum housing. If we provide good shelter for those people, the standard of their living will improve, and with that, their healthcare and education will improve. In fact, I believe that Contour Crafting is a crucial technology for India.” Indeed, developing countries like India in particular and the world in general cannot ignore Contour Crafting’s potential in quickly and efficiently alleviating housing problems.

Space colonies: With the advent of the 21st century, the human race is looking more confidently at establishing habitats on the other land surfaces in the solar system. It may not be long before advances in space technology make it possible to live on the Moon or Mars. NASA plans to undertake extended human missions to the Moon as early as 2015, with the goal of living and working there for increasingly extended periods. Naturally, habitats have to be established on the lunar surface prior to any explorer or settler spending extended periods of time there.

Being a robotic technology, Contour Crafting has the potential to build safe, reliable, and affordable structures on the Moon. Given this potential, Contour Crafting construction systems are being developed that will exploit in situ resources and can utilise lunar regolith as construction material. These lunar structures can include integrated radiation shielding, plumbing, electrical and sensor networks. Dr Khoshnevis elaborates, “The ability to fabricate extra-terrestrial habitats, laboratories or manufacturing facilities is the key element for long-term human survival on the Moon or Mars. Our proposal develops an automated in situ construction system that is viable, economical, practical and with applicability within a decade for Earth-Moon operations.” Suddenly, the future seems to be an interesting place to be.

Commercial advantages

Contour Crafting can significantly reduce the cost of construction for commercial, industrial, military and government buildings. Projections indicate that the costs will be around one fifth

Dream machine for architects

Would a technology driven innovation like this become popular with architects? Dr Khoshnevis strongly believes so: “Architects are the strongest advocates of this technology, because for the first time they will be enabled to implement intricate designs using curved features and complex structures without incurring excessive construction expenses. Furthermore, such designs are currently not possible to implement where there is shortage of skilled workforce. Many famous architects around the world are in contact with us and are inspiring us with great ideas. We also believe that architects will eventually be the drivers of this technology. Consider these two analogies: When movie camera was invented, the art of cinema was non-existent. When computer printers first came out, there were no fancy fonts or desktop publishing software. Many creative people used the movie camera and the printer technologies to create wonderful stuff. The CC technology will provide a very capable 3D printer with which anything can be fabricated. The rest will be left to the imagination and creativity of architects and even novice designers to change the look of our homes, neighbourhoods and cities.”

that of conventional construction. Dr Khoshnevis believes that, “Contour Crafting construction projects will be extremely accelerated. This rapid construction time minimises the financing costs of construction projects that typically take six months or longer to complete. While the costs of manual labour will be significantly reduced, physical power will be exchanged for brainpower in the construction industry. Construction could become a consumer market, wherein a house or alternate structures could be designed and built by the family that will occupy it. Reduced costs and automated building will make construction accessible to anyone.” It wouldn’t be illogical to imagine a time in the future when the Contour Crafting machine will be available at the local hardware store for sale as well as for hire.

Safety and environmental aspects

Contour Crafting will prove to be much safer, both for the worker and the environment.

Safety first: Annually, thousands of workers are seriously injured or killed on construction sites throughout the world. The fact is, construction jobs are dangerous and take a heavy toll on human life and resources. Commenting on Contour Crafting’s usefulness with regards to this important aspect of construction, Dr Khoshnevis says, “Since it is an automated

robotics technology, workers will not have to risk life or limb to do backbreaking and repetitive tasks. The resulting reduction in labour injuries and the subsequent litigations will reduce both the human and financial costs of construction.”

From the safety perspective, the following benefits can be identified for employing Contour Crafting technology:

- ▶ Less injuries in construction and transportation-related activities
- ▶ Less human contact with hazardous substances
- ▶ Less exposure to airborne substances such as dust and chemicals
- ▶ Less noise exposure
- ▶ Easier to establish procedures for hazard and failure analysis during construction.

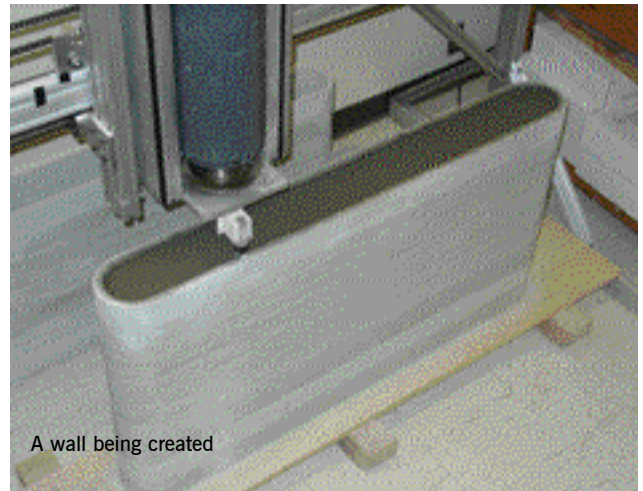
Environmental aspects: Globally, the construction industry has a huge negative impact on the environment through exploitation of natural resources and through generation of construction waste. In addition, it contributes significantly to environmentally harmful emissions.

Contour Crafting is a robotic technology with very accurate computer control. Due to the nature of this technology, materials are extruded with perfect precision and near zero waste. Dr Khoshnevis explains the benefits, “Contour Crafting offers construction without waste, noise, dust or harmful emissions. As a result, construction by Contour Crafting will be an environment friendly and sustainable process.” The proposed technology could result in the following environmental health and safety benefits:

- ▶ Less total material use
- ▶ Less total energy use for all construction activities
- ▶ Less material and energy waste during construction
- ▶ Less transportation of material, equipment and people.

During the use phase, there will be:

- ▶ More efficient buildings and therefore less energy consumption in HVAC
- ▶ Efficient internal space use for occupants
- ▶ Increased structural strength and durability due to less aging material
- ▶ Increased seismic safety due to improved construction design and material.



The way ahead

Given the fact that most components required for the technology already exist in other sectors, it wouldn't be long before Contour Crafting hits the market. So, are there any major issues that still need to be addressed to make the Contour Crafting Machine commercially feasible and available? Dr Khoshnevis clarifies, “We are in the final phases of constructing the first CC machine, which will be able to build full-scale houses. Within the next three months we will build the first full-scale house in our laboratory to establish the feasibility of the approach (although we have already constructed full-scale concrete wall sections). We do not anticipate to have any major technological problems. The major problems will be policy issues (such as building code conformance) and possibly employment issues. We anticipate that the first commercial applications will be available in two to three years, starting with emergency shelter for disaster areas and low-income housing.” That definitely is not very far away.

The issues mentioned by Dr Khoshnevis are certainly very pertinent. But universally speaking, the basic parameters to judge any technology should be its overall serviceability in practical terms and its ability to propel the human race forward. Contour Crafting, in the long-term, has the potential to score brilliantly on both these accounts. So, along with a revolution in the built-world, a dramatic social change is also in the offing. Nonetheless, whatever the social impact, one thing is for sure; the construction industry is in for a paradigm shift.

