

Contour Crafting: A Future Method of Building

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Abstract Building a house using 3-D printing technology is available to people in near future. Contour crafting is the method that can build a house quickly, safely, and economically. Since the robots and computers are the main part of the construction, human labor restriction that causes expensive and inefficient construction will be no longer a problem. Thus, numerous applications can take advantage of the benefits of this technology, such as low-income housing, emergency housing, and even space colonies. Although there are some ethical issues of temporary job loss of current construction workers, huge benefits of contour crafting will outperform few social issues.

3-D Technology

Now people can print out spoons, hammers, and even guns in an instant in the comfort of their homes. Did you ever think that we would create 3 dimensional objects from a printer? The 3-D printer is one of the most revolutionary inventions of the 21st Century. It has tremendous applications in so many different areas of our daily lives. For instance, in certain industries, it will be able to make prototypes instantly and rapidly manufacture products. Also, the mass customization will soon be available to consumers. Then engineers wondered whether 3-D printing is feasible when it comes to building a real size house. The answer turned out to be positive. In the near future we will be able to print out homes from building designs from a computer by using contour crafting.

Introducing Contour Crafting

To print a building, no current commercial 3-D printer would be feasible due to its size limitation. Thus, Professor Behrokh Khoshnevis, from the University of Southern California, developed contour crafting—a layered fabrication technology that can build larger objects quickly. Figure 1 is a diagram of contour crafting for constructing buildings.

As shown, two parallel rails let the gantry system move right or left. The two pillars on top allow movement up or down to precisely extrude the special concrete materials or to place the construction materials on the right spot [1].

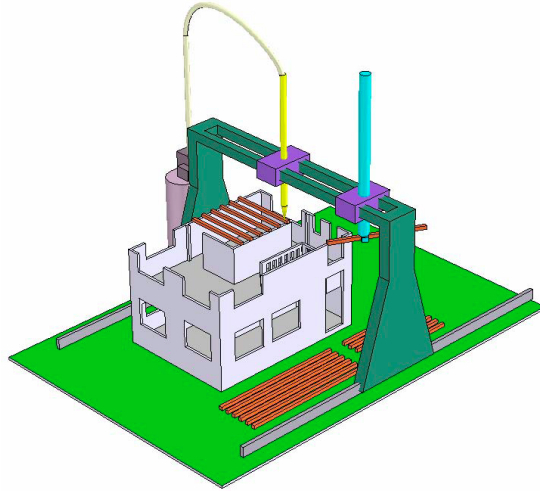


Figure 1. Example of Contour Crafting construction [2]

How does it work?

The basic idea is that the extruder goes around the building's margins to construct the walls. When one layer is done, it automatically moves up to build the next layer. The building will be done slice by slice until it reaches the desired height. Other materials, such as roofs, pipes and window frames, will be placed by another robot (blue column in Figure 1) on the gantry. This robot will simply pick up the materials and place them on the right place and right time. Glass windows, however, will still need human labor because of its fragility. In this building process, there are two key parts that make contour crafting superior to any other layered fabrication technology [1]. Figure 2 is a close shot of the extruder. As shown in figure 2, the two trowels (indicated in red) create buildings with remarkably smooth surfaces while eliminating any trace of the layers. Depending on the shape and the angle between the trowels, various designs can be built. Thus, the

quality of construction is much superior and flexible in making any kind of building. For those who wish to watch an animation of the procedures of building a house by contour crafting visit link [3].

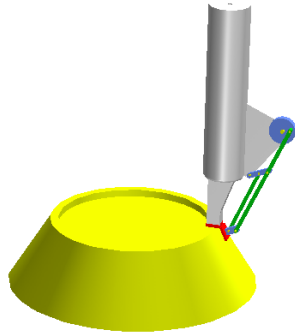


Figure 2. Extruder and Trowels (red part) [1]

To create a building with contour crafting, engineers or architects must design their buildings in CAD. Then, the designs are analyzed and verified by civil engineers, and should pass all the governmental regulations [4]. Then, they need to find the most appropriate material to build the outline of the house. The materials may differ according to the characteristics of the terrain, cost-effective supplies of the materials, and the type of the building. Some examples for the material would be concrete, adobe, clay, and other additives [5].

Where can we use this technology?

Contour crafting technology is relatively straightforward and simple, but there are so many different approaches when applying this technology to the real world. Some of the most significant benefits of Contour Crafting are short construction times, no human workers, cheaper cost, and flexibility of materials. These characteristics gave researchers several brilliant applications.

Commercial Applications

The United States spends 1 trillion dollars annually for national construction. However, the costs of the construction include huge amounts of material waste, labor problems, and uneconomical building designs. Also, many lives are risked on construction sites [6]. 114 people died when constructing the Hoover dam [7]. Moreover, conventional construction is not environmentally friendly, since it produces significant amount of air, water, and noise pollution. So, how can Contour Crafting change the commercial construction?

Hundreds of thousands of people get injured or killed annually at construction sites [6]. The most common fatal injuries are burns, head injuries, spinal cord injuries, and bone fractures. Contour crafting, however, make robots do the risky work, preventing any kind of human injuries or deaths. Also, Contour crafting, a computerized and robot-centered technology, will lessen the harmful environmental impacts. Since materials will be precisely measured prior to construction, there will be no leftover material waste. Also, it will produce significantly less water, air, and noise pollution than the conventional methods [1].

According to the researchers, the cost of the construction will be one fifth of what it used to be [8]. The technology minimizes the material waste and construction time, which leads to significantly low total cost. Also, labor power will be replaced by intelligence. Thus, not only woman, but also elderly people will be able to take part in the construction industry. In the end when people use Contour Crafting, the commercial industry will not be restricted by inefficient costs and human labor, while being green [8].

Low-income Housing

As of today, there are 7 billion people in the world, and this population is growing faster than ever. Populations in developing countries are growing five times faster than those of developed countries [9]. So, what is the problem here? More than 90 percent of the population growth is taking place in the developing countries. They do not have proper infrastructure, residences, or money to afford such population boom unlike the developed countries. Figure 3 is a picture of a slum in India. Slums form because the country's rate of urbanization is too slow to accommodate all of low-income citizens. As a result, more than one billion people do not have proper homes [9].



Figure 3. A Slum in India

How can Contour Crafting resolve this issue? The main problem of developing countries is that they do not have enough money to develop cities and residences in a rate similar to that of the population growth. The cheap and rapid characteristic of Contour Crafting provides a solution, since a fully functional house can be made in less than a day. By using such a technology, developing countries will be able to solve housing problems of the current and future population [9].

Emergency Housing

In the world we live in, people are prone to some kind of emergency due to a war, natural disaster, or economic crisis. In the state of Oklahoma there had been two dreadful tornadoes in May and June of 2013. This catastrophic event caused the death of more than thirty people and destroyed hundreds of houses. Worldwide, there are about 37 million people who lost their homes through no fault of their own like victims in Oklahoma [10]. What will be the best for them? Probably a home. The United Nations has helped those people with prefabricated houses, but they were not cost effective. They were poor in construction quality, expensive to transport, and lacked necessities, such as heating and plumbing [11].

How can the UN and other aiding organizations better accommodate victims of such unavoidable disasters? Researchers are taking Contour Crafting into account because its unique characteristics are able to assist these victims in need. It creates a fully functional house, including plumbing and heating, within a day. Also, there will be no cost for material transportation because it can utilize local construction materials. Since building houses does not require labor, workers can focus more on other infrastructural reconstructions to accelerate the recovery process [11].

Space Colonies

The growing curiosity of outer space has never been fully answered. Studying space can help people understand how they came to life and what else is out there. Thus, people have been studying space ever since the earliest civilization such as Mesopotamia [12]. The best way to study outside the boundaries of Earth would be to go out and explore for ourselves. The first steps of research seem to be applicable on the Moon and

on Mars. But before any of the human missions, researchers must send robots to set up appropriate habitats that can last extended periods for research [13].

Contour crafting is the best solution for any extraterrestrial construction that NASA approved [14]. Since people are already using tremendous amounts of money on shipping research machines from earth to another planet, they need to minimize the cost on the actual construction. Also, astronauts do not have much labor power and time to construct buildings by themselves. Sending construction materials from Earth will be too expensive and inefficient to carry out. Figure 3 is a drawing of lunar Contour crafting. As shown in the drawing, there is no need for human labor. Also, Contour crafting uses materials that are available on site [13]. Therefore, this technology will make the best option for outer space colonies and explorations.

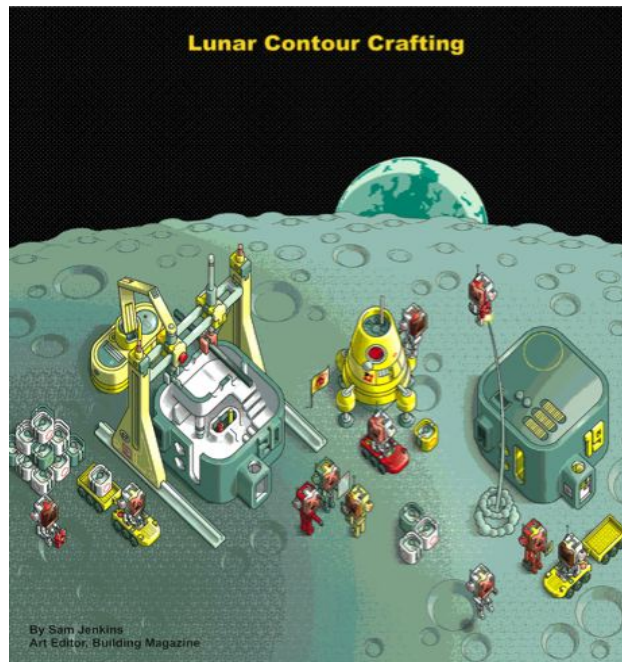


Figure 4. Lunar Contour Crafting [13]

Ethical Issue

Unfortunately, new technologies tend to provoke ethical issues. For Contour crafting, the automated process of commercial construction will cause issues with the workers and construction firms. Will the labor unions approve the new technology? Although Contour crafting prevents workers from injuries and deaths, it also leads to their unemployment.

Current/ Future Research Plans

Currently, University of Southern California has several contour crafting machines under Professor Behrokh Khoshnevis' supervision. They are fully functional and have developed for researching construction materials and additives that are put into the gantry. Also, to experiment possible designs of buildings, engineers are making numerous 2.5D and 3D shapes by using contour crafting. Another recent research is the reinforcement of wall constructions. They have been studying the wall by inserting different shapes, sizes, and materials of coils in between the layers [1]. Most recently they have been developing a new nozzle that can be used in full-scale constructions [1]. Figure 4 is the new nozzle for full-scale construction. The new nozzle can extrude three different materials at once, which makes the process more flexible and feasible. For example, walls with conduit and unsupported rooftops can be built by using this new nozzle [1].

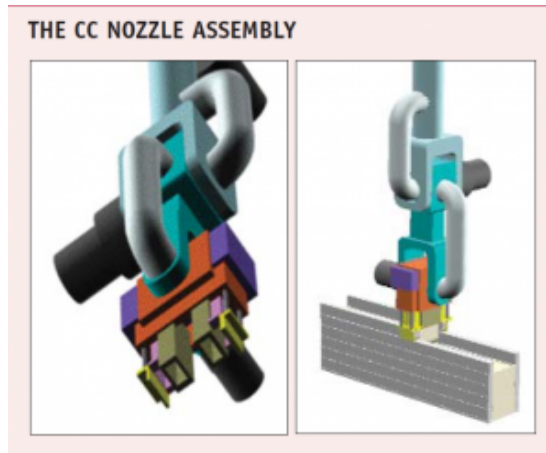


Figure 5. A New Nozzle [1]

In the future, research will focus on the robotics and the programming of contour crafting. Robots could become more mobile, that will allow a more complex architecture construction. Also, the construction time could be controlled since consumers can pay more to use more robots if they wish [1]. However, the most important part is IT. There are so many things to be done before contour crafting becomes commercialized. The examples of programs include analysis of contour crafting feasibility, city inspection requirements measurement, high-level planner/organizer, multi robot controller, logistics planner, dynamics analysis, and the main controller system [1]. All of this research will require lots of effort from scientists and engineers.

Conclusion

Contour crafting is a huge step towards the future. It will affect people's daily lives, the construction industry, and even outer space missions. Its practicality is incomparable to conventional construction methods. It is cheaper, faster, safer, and easier than any other method. There will be, however, potential problems with labor unions and other construction companies who have been building manually. These problems are

complicated, and engineers do not have the solutions to them fact. Because this technology is only at the developing stage, it is difficult to address solutions to problems we may face. One thing sure about contour crafting is that it is a powerful potential construction method of the future, and it needs more public attention for more funds and extensive research [15].

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