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Contour Crafting (A Management Tool for Swift Construction)

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Abstract - *Contour crafting (CC) is a layered fabrication technology used to build houses, buildings, towers, etc. that uses a computer automated crane or gantry to build rapidly and steadily with considerably very less manual labor. CC is the newly emerged construction technology delved by Dr. Behrokh Khoshnevis of the University of California. He decided to accustom this technology for a quick construction of homes in areas affected by natural disasters like earthquakes that has devastated many countries. In the CC construction process, a precise amount of mortar mixture is delivered to make a concrete mold using robotic techniques. Mortar mixture is added in a layer by layer fashion; then a volume of commercially available concrete is poured with a certain time delay between batches. The CC construction process has great potential in construction automation due to its relative simplicity, low cost, and capability of being easily integrated with currently available automation technologies. This is demonstrated by CC's unique capabilities and experimental results in fabricating a full-scale concrete wall structure using ordinary construction materials*

Key Words: Contour Crafting, construction automation, fabrication, layered fabrication process, future construction.

1. INTRODUCTION

Contour crafting is a building printing technology being researched by Behrokh Khoshnevis of the University of Southern California's Information Sciences Institute (in the Viterbi School of Engineering) that uses a computer-controlled crane or gantry to build edifices rapidly and efficiently with substantially less manual labor. Khoshnevis stated in 2010 that NASA was evaluating Contour Crafting for its application in the construction of bases on Mars and Moon. In the same year he stated that this system could build a complete home in a single day, and its power crane that is electrically operated would produce a very little construction material waste. After three years, in 2013, NASA funded a small study at the University of Southern California to further develop the Contour Crafting 3D printing technique. Contour Crafting (CC) seems to be one of the layered fabrication technology that is applicable to construction of large structures such as houses. The construction automation will require a paradigm shift in process technology. The Contour Crafting construction process, fits in this category and has the potential to revolutionize the industry, changing it from the conventional "cast-in-place" paradigm to a layer by layer approach. The aim of this technology is to improve the speed, safety, quality and cost of construction.

1.1Contour Crafting

"Contour Crafting is an additive fabrication technology that uses computer control to exploit the superior surface-forming capability of troweling to create smooth and accurate planner and free-form surfaces out of extruded materials." (Zhang & Khoshnevis) Contour Crafting seeks to increase safety standards (both for occupants and laborers) and construction efficiency at a time when: "Labor efficiency is alarmingly low, accident rates at construction sites are high, work quality is low, and a skilled workforce is vanishing." As the population in developing countries grows rapidly, traditional methods of construction will not meet housing demands, especially in areas where a higher construction standard is required for safety precautions. Contour Crafting seeks to address housing problems and provide people in all countries and all societies with affordable and dignified housing.

2. CONTOUR CRAFTING PROCESS

The CC process is based on an extrusion and filling process the extrusion process forms the smooth object surface by constraining the extruded flow in the vertical and horizontal directions by trowels. The orientation of the side-trowel is dynamically changed for better surface fit. The side-trowel allow thicker material deposition while maintaining high surface finish. Thicker material deposition cuts down manufacturing time. It is essential for building large- scale parts using the additive process. The maximum deposition of layer thickness is limited to the trowel height. As the extrusion nozzle moves according to the predefined material deposition path of each layer (rims) are first created. The troweled outer surface of each layer determines the surface finish quality of the object. The top surface of each layer is also important for building a strong bond with the next layer. The boundaries of each layer are created the filling process begins and material is injected to fill the internal volume.

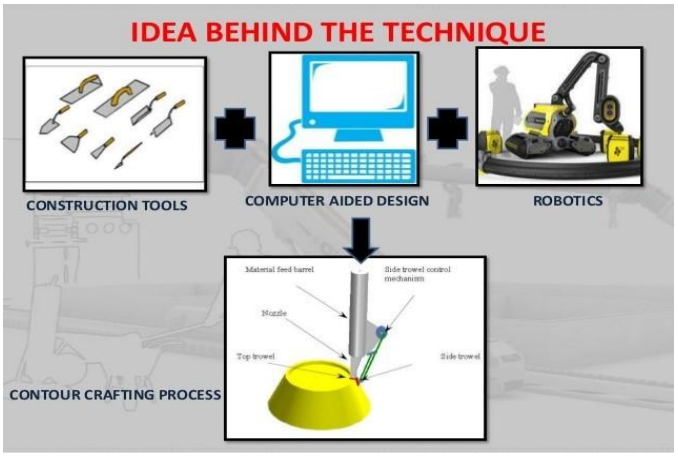

Fig 2.1 Diagrammatic representation of CC process

The basic idea is that the ext-ruder goes around the building's margins to construct the walls. When one layer is over it automatically moves up to build the next layer. It will be done slice by slice until it reaches the desired height. Other materials like roofs, pipes and window frames will be placed by another robot on the gantry. It will simply pick up the materials and place them on the right time. In the case of glass windows still need human labor because of its fragility. There are two key parts that make Contour Crafting superior to any other layered fabrication technology. The two trowel create buildings with remarkable smooth surfaces while eliminating any trace of the layers. Depending on the shape and the angle between the trowels, various designs can be built. The quality of construction is much superior and flexible in making any kind of building.

To create a building with Contour Crafting, engineers or architects must design the buildings in CAD. Then the design are analyzed and verified by civil engineers, and should pass all the governmental regulations. The materials for construction may differ according to the characteristics of the terrain, cost-effective supplies of the materials and type of the structure.

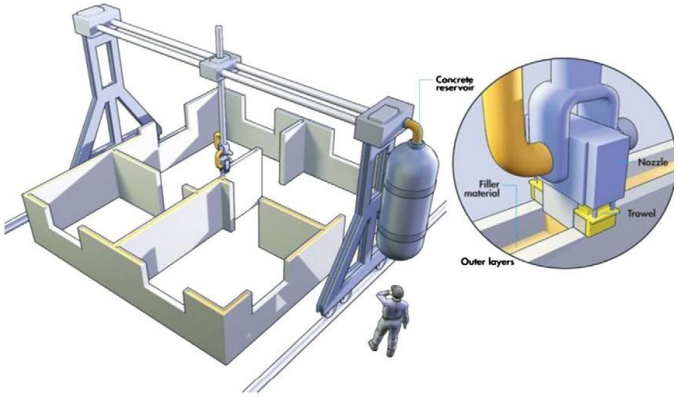

Fig 2.2 The Contour Crafting Machine

3. Applications

Applications of the contour crafting technology may include various types of building constructions including housing, commercial and government buildings. Another application domain is infrastructure construction which could include foundations, slabs, bridges, pylons, etc. And finally extra-terrestrial construction, that is, building on Moon and Mars for planetary exploration, exploitation, habitation and colonisation is another major field of use of contour crafting technology. The major applications of contour crafting technology are a) Building Construction b) Infrastructure c) Space Applications.

Building construction

Fig 3.1 CC in building construction

Cost:

Contour Crafting is an alternative that can decrease about four times of the construction cost because of its simplicity, materials' saving and short time productivity (10 houses in one day, for example). In addition, it can give more liberty to design projects that might be easily done without much difference (in terms of cost and feasibility) from simple projects.

Labour:

The great advantage of this technology is the use of few workers at the construction site. Only specialised people (computer and management skills) would be required to operate the machine. Due to this fact, not only men would be able to work in construction, but women and elderly people as well. In conclusion, CC machine does not get tired, does not give excuses of failures, and does not need to be trained. In contrast, it might work 24 hours a day, thus it speeds up the job schedule.

Safety:

With Contour Crafting, work injuries and fatalities are reduced to zero because of the very safe method of construction. As it has a low number of workers and a computer executes almost everything, it does not bring any danger to the construction site.

Sustainability:

Due to its accuracy, Contour Crafting technology provides construction without waste, being considered as environmental friendly and a sustainable process, consequently. In addition, it does not make any noise, besides of being a fast process. It uses less material, less energy for all construction activities and less transportation of material, equipment, and people.

Productivity:

With Contour Crafting, 10 houses can be built in a single day, or even more. This method does not use form-work, which is a shortcut in the construction time. Computers execute everything in the construction, so it might be as much as 50 times faster than conventional method. In addition, this method is very accurate to execute its assigned commands, so it is able to make its jobs faster.

Infrastructure

Fig 3.2 Infrastructure by CC Technology

Many types of infrastructure elements may be automatically built with variations of the CC technology. A small-scale version of the system has been constructed and the feasibility of the concept has been proven. Future plans of CC Corp includes the development of full-scale CC tower builders.

The major advantages of the new approach are:

- Fully autonomous operation
- Usage of concrete that eliminates factory work on steel segments and difficult transportation
- Safe operation due to elimination of human tasks at risky elevations and windy condition
- Low cost of transportation
- Possibility of building much taller towers

Space applications

Fig 3.3 Building Construction in space by CC Technology

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. Contour Crafting technology has the potential to build safe, reliable, and affordable lunar and Martian structures, habitats, laboratories, and other facilities before the arrival of human beings. Contour Crafting construction systems are being developed that exploit in situ resources and can utilize lunar regolith as construction material.

These structures can include integrated radiation shielding, plumbing, electrical, and sensor networks. Economically viable and reliable building systems and tool sets are being sought, examined and tested for extra-terrestrial habitat and infrastructure buildup. This proposal uses a unique architecture weaving an automated building technology called Contour Crafting with designs for assisting rapid buildup of an initial operational capability lunar base. Using CC technology, this proposal intends to draw up a detailed plan for a high- fidelity simulation at NASA's Desert Research and Technology Studies (D-RATS) facility, to construct certain crucial infrastructure elements in order to evaluate the merits, limitations and feasibility of adapting and using the CC technology for extra-terrestrial application. Elements suggested to be built and tested include roads, landing pads and aprons, shade walls, dust barriers, thermal and mm protection shields and dust-free platforms as well as other built up structures utilising the well known in-sit-resource utilisation (ISRU) strategy. Several unique systems including the Lunar Electric Rover, the unpressurised Chariot rover, the versatile light-weight crane and Tri-Athlete cargo transporter as well as the habitat module mockups and a new generation of spacesuits are undergoing coordinated tests at NASA's D-RATS. This proposal intends to draw up a detailed synergetic plan to utilize these maturing systems coupled with the CC fabrication technology, tailored for swift and reliable lunar infrastructure development. This proposal intends to increase astronaut safety, improve build-up performance, and ameliorate lunar dust interference and concerns, and attempts to reduce time-to-commission, all

in an economic manner. As part of this proposal, a figure-of-merit methodology will be created and employed to gain some quantitative insight into the efficiency of using the CC technology to augment these other systems already in place.[11]

Environmental effects:

Traditional construction necessitates the use of different machinery, totally consuming a great deal of energy and releasing too much CO2 into the environment. Using CC machine which works on electricity, the emission rate of CO2 decreases remarkable yearly in proportion to construction industry.

4. CONCLUSION

This research has aimed at providing a systematic methodology for process planning and optimization in order to efficiently construct complicated large-scale structures by Contour Crafting systems using different hardware configurations. Due to its speed and its ability to use in-situ materials, Contour Crafting has the potential for immediate application in low income housing and emergency shelter construction. Contour crafting is a very powerful tool that can be used in AEC (architecture, engineering, and design) applications, since it can build small scale architectural purposes models up to real life scale engineering projects, in more efficient ways. It can also achieve very complex structures that are hard to build using conventional methods, and which are more structurally sound then the present design of buildings. Contour Crafting is that it has a great productivity, building houses in a matter of hours, without wasting any material.

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