Automation in Construction: A Survey

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Abstract

Large construction project comprises of many different parts and most of them are done manually. But the manufacture industries producing goods are now fully automated. As a result, the production cost and production time decreased and quality of the product increased. On the other hand every construction needs extensive physical labor just like the production system before the era of industrialization. Therefore, automation in construction will make the process efficient, fast and cost effective. Now-a-days there is a few number of automated and semi-automated systems are being used in the construction projects. This paper provides a survey, analysis and comparison on those automated and semi-automated systems. The goal of this survey is to present the advancement of automation in construction and the limitations of the systems which is a potential area for further research and those research will help to upgrade the present systems or invent a new, more effective and a robust model.

Keywords*: automation, navigation, SAM 100, In situ, Hadrian X*

1 Introduction

We are living in the world of technology. The technology has improved to a great extent in recent days. Our everyday life has changed for that. Now we see the domination of artificial intelligence. From our home to large industry we see the use of automated systems such as robots which have artificial intelligence. Moreover, it tries mimics human brain. Today our indoor systems are automated and the production of goods are also being automated in course of time. Automation can be defined as the technology by which a process or procedure is performed without human assistance (Groover and Mikell, 2014). Then why can't we use this revolutionary technique in Construction? We are going to analyze the existing automated systems which are already being used in construction. Then we will try to get some insights and try to develop new ideas to improve the automation techniques.

The construction process has a significant influence on global economy. From statistics we can see that these construction industry comprises of 10% of world's GDP in developed countries and 25% in developing countries (Mi Jeong Kim, at al., 2015). For example, in Japan, a developed country, the total scale of construction is about 50 trillion yen and about 6 million workers work there which comprises of 10% of total population (Yukio Hasegawa and Professor Emeritus, 2012). We can also see that more than 26,000 U.S construction workers have died during construction in the last two decades, which implies that 5 construction workers dies every working day (Sijie Zhang a, et al, 2012). This accident rate can be reduced or stopped if automated system is introduced. Recently China built 57-storey skyscraper - in just 19 days. It is an outcome of automated system in construction (independent.co.uk news). Automation in construction is becoming more and more popular throughout the globe.

Industry 4.0 is the modern trend of automation in the sector of manufacturing industries (Wikipedia). It is called the “Smart Technology”. It has four stages of automation which is a general timeline of development of automation in the manufacturing process.

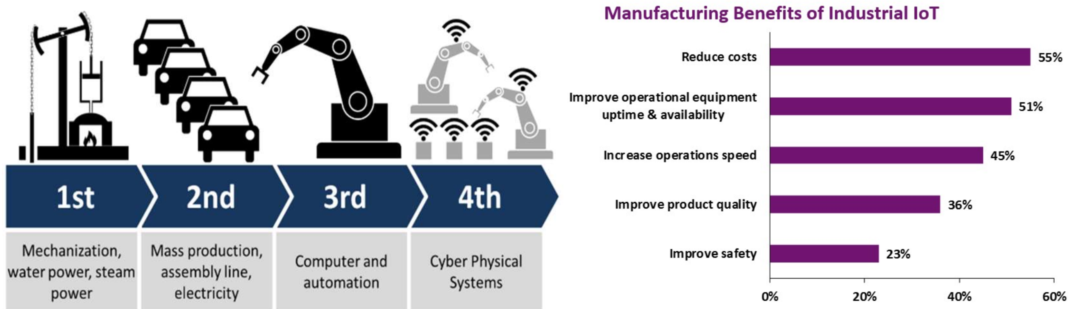

Figure 1. Industry 4.0 model (Wikipedia) and Benefits of automation (Aberdeen Group, March 2017)

But today most of the construction are done with manual labor which is a major drawback of the modern era. However the use of machine and mass production which refers to the first two parts of the industry 4.0 has been implemented, it is a high time we implemented the computer and automation. If we take a look at the industries, we will observe that automation has increased the production rate, reduced the cost and over all increased the revenue which is the main objective of any production company. So if we can somehow implement the idea of automation just like the industries, we can increase the output, reduce the cost and time. Implementation of automation in construction is the prime goal of this research.

2 The Survey

2.1 SAM 100:
Semi-automated mason is a brick laying robot designed and engineered by Construction Robotics. This was first invented on 2015 and won the most innovative product industry choice Award. Now it is greatly enhanced. In 2017 it launched SAM100 OS 2.0 which is much faster than the previous one (masonryconstruction.com). SAM 100 has worked in more than 19 states and worked on more than 29 construction site (construction-robotics.com). It costs around $500,000.
It does the following tasks:

a) picking up bricks
b) applying mortar
c) Sensing the location
d) Placing them in their designated location (www.technologyreview.com)

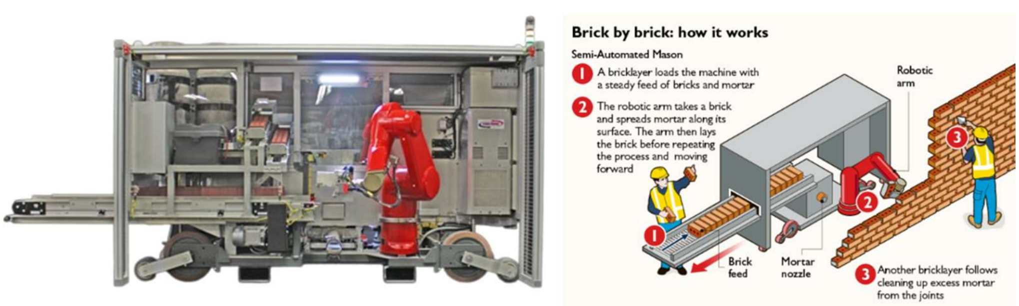

Figure 2. Illustration of working method of SAM 100 (www.zerohedge.com/news)

It can collaboratively with the mason team. Its production rate is consistent and the installation cost is low. As this is a semi-automated the mason need to work with it. They can work together. The robot can do the repetitive tasks in a short time.

This robot can lay about 3000 bricks in one day where a human can lay about 500 brick per day which seems a great difference (pressreader.com)

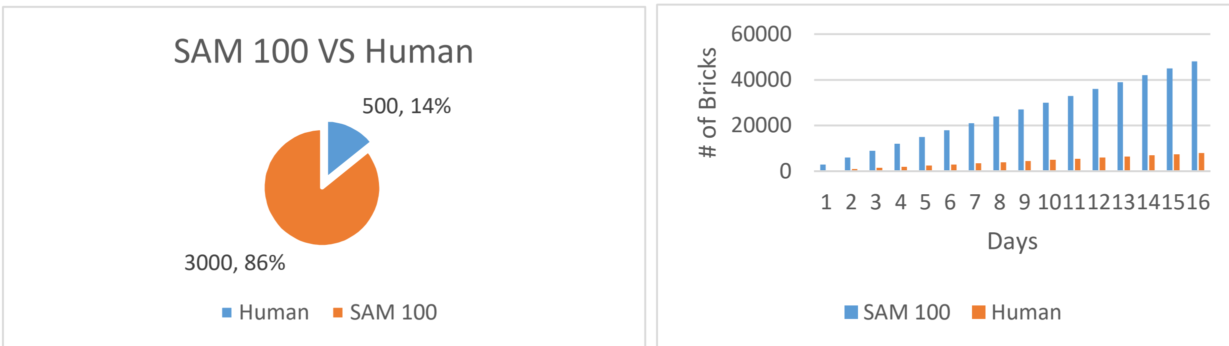

Figure 3. SAM 100 VS Human Worker

Let's consider a high rise building with 50 floors and 20 rooms in each floor. For simplicity we can assume every room's dimension is same. Let's say dimensions are 20x10x8 cubic feet. We are going to use bricks to build that house. To calculate the number of bricks needed to build that house we need to get the size of a brick. Let's assume its dimension is 10x5x3 inches. So we need approximately 2300 bricks. In 16 days human can lay 8000 bricks where this robot can lay about 48000 bricks. So if from this calculation, we can see that one human labor can build only three rooms where the SAM100 can build 20 rooms, a complete floor, in just 16 days.

2.2 In-Situ

In-situ is an onsite construction robot which can build a wall without human touch. Architects and robotics scientists of Zurich developed this automated construction robot in Switzerland. To show off its capabilities, Giftthaler, the lead scientist of the inventor team, with his co-workers used it to build a pair of structures in an experimental construction site in Switzerland called NEST (Next Evolution is Sustainable building Technologies). The first is a double-leaf undulating brick wall that is 6.5 meters long and two meters high and made of 1,600 bricks (technovelgy.com). This is a mobile robot that means it can move from its position when needed. It can build stuff using a range of tools with a precision of less than five millimeters which is very accurate. This operates semi-autonomously in a complex changing environment where the construction site is continuously changing. It can reach up to a wall height.

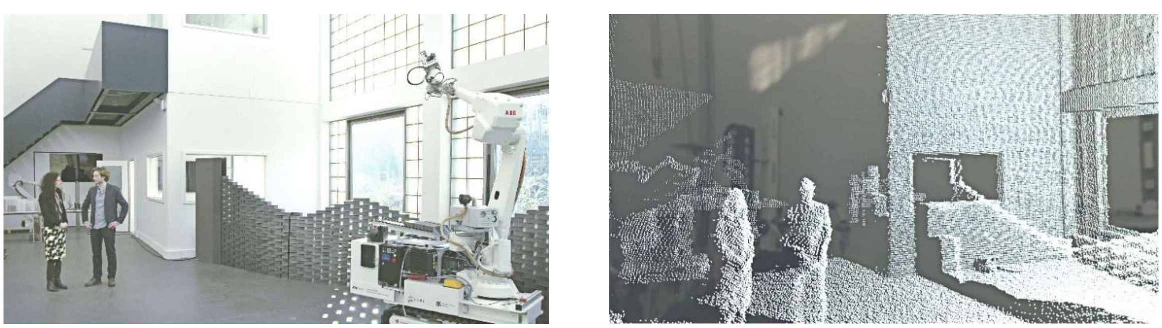

Figure 4**.** 3D map of the construction site with its 2D laser range-finder by In Situ Fabricator

In Situ Fabricator1 constructs a 3D map of the construction site with its 2D laser range-finder, together with computer algorithms (mirror.co.uk/news). This map is used for the placement of the bricks and detect other objects like human and non-construction objects. The map allows the robot to navigate in the construction site without human aid (inhabitat.com). It runs with standard electricity but it also has battery backup. This robot needs internet connection to feed the plan and do modification when needed (technovelgy.com).

2.3 Hadrian X

Mark Pivac who is an aeronautic and mechanical engineer is said to have been working on Hadrian since 2007. It was developed in Australia. The Hadrain 105 successfully completed the first block printed structure from a mobile base 20 meters in 2015. It has a bricklaying rate of 225 per hour which seems slow compared to human (Wikipedia and fbr.com.au). This robot is a 25 ton machine and can reach out 28 meters (robohub.org). So it can reach over the entire building site. The laying head, the position is monitored in six degrees of freedom. Three linear XYZ coordinates and also the orientation by laser tracker and a smart track sensor. The co-ordinates are read in a very high speed, some are in the order of 100 Hertz to 1,000 Hertz.

Then an upgraded version of Hardrain came in to play in March 2015. It is known as Hadrain X. The Hadrain X is built by using steel, aluminum and carbon fiber. This robot is controlled by robot vision, servo motors and most importantly laser trackers to monitor its laying position. First an engineer or an architect need to make a 3D model of the building and this model is used to guide the robot. But the model cannot be fed in as it is. It is first converted into machine code, then the code is supplied to the robot. The laser guides the robot physically. The laser surveys the foundation. Then it uses a 28m articulated telescopic boom. The laser ensures the accuracy with maximum error of 0.5mm (robohub.org). It can also detect doors, windows and other things automatically from the model and acts to it (Wikipedia). No human hand is needed to touch a brick during the loading, cutting and laying process. It's fully automated from the start to end. Completed walls will also have the channels routed to accept electrical wiring and plumbing. This channels are made in a dust and noise suppressed section of the machine prior to laying the bricks (designingbuildings.co.uk).

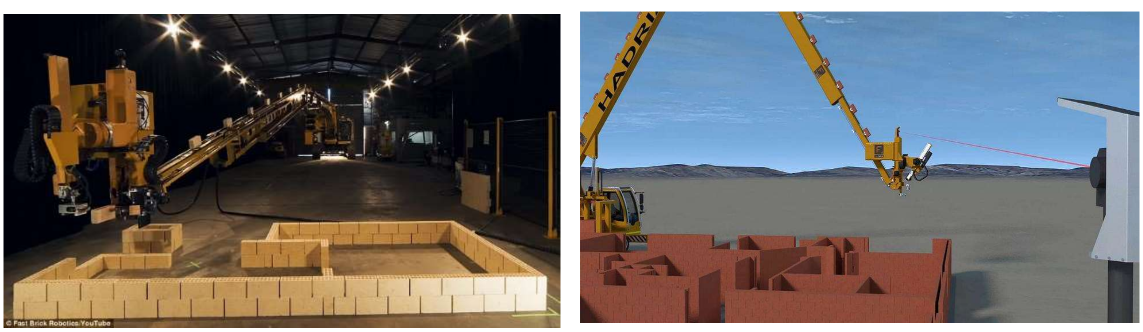

Figure 5. Navigation system by a laser and a sensor

This robot can handle the bricklaying process from end to end. From the moment the bricks are delivered to the building site through to the time of the finished house or structure. The total approach is automated (robohub.org). This automated robot doesn't user normal mortar. It uses special adhesive. This robot can lay 1000 bricks per hour with high degree of accuracy and can work nonstop 24 hours. Hadrian X uses specialized industrial adhesive, which is said to strengthen the structure by four to five times (Wikipedia). The **Hadrian X** will cost approximately AUD $2 million per unit (robohub.org).

2.4 Shotcrete

Shotcrete or sprayed concrete is concrete or mortar conveyed through a hose and pneumatically projected at high velocity onto a surface, as a construction technique. It is typically reinforced by conventional steel rods, steel mesh, or fibers (Wikipedia).

Figure 6. Spraying concrete (idn.sika.com)

3 Analysis

SAM 100 is a very successful semi-automated construction robot which is already being used in many construction projects. And it is a high performance robot. The researchers who invented it is trying to upgrade it. But the current version is performing much better and faster than a human worker. In situ is another robot which uses computer vision to construct a 3D map of the construction site and uses the map for navigation and to detect the construction areas. So, it needs a powerful system for Image processing and navigation. As a result this is somewhat slow. But it is fully automated. Hadrian X is a very powerful fully automated system for construction and it is faster than all other system built today. But limitation if all these system is that they can work only as a brick builder. It cannot apply mortar which is a great drawback of these system.

4 Conclusion

Automation makes our life better and easy so as in construction. Not only it has ease the human labor but also it has made the construction faster and more cost effective. Currently there is a number of automated construction system which are available in the market and many other under research. But still there are some parts which are untouched by the automation. One most important part of construction is the construction of beam and yet it is not been automated.

5 Future Work

In this paper we have surveyed the latest technology in the field of automated construction. And we have introduced a new idea to construct beam, column and sabs with premade reinforcement structure. For future we are going to analyze more on this area and will try to make a working robot which can actually do this. Moreover we will search for some field which is not automated till now and will try to automate it. For example, making the reinforcement beam, ring beam etc. structure is still done manually. So we are going to focus on those manual parts in the future. We have started working on computer vision to recognize the beams bare bone structure with machine learning which is a very popular field of artificial intelligence. When it’s done, we are going to make a model to perform this task.

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