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The Construction Robots and Pathway to Implementation

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ABSTRACT

Construction automation is generating much interest in the construction community over the last two decades. Conventional industrial robots occupy a fixed position within a work cell and the work-piece is brought to the robot. But, construction robots must travel to the workplace. A key requirement is the ability to move successfully from one work location to another. The robots employed in construction have followed the same concept as those employed in manufacturing. Building robots have been employed in various tasks including materials handling, various interior and exterior finishing tasks, and quality control. The serious problems faced by the industry are continuously declining productivity, low labor efficiency, high accident rate, low quality; insufficient control of the construction site, and the vanishing of a skilled workforce. The reasons for this situation are identified as existing robots are not well adapted to building construction, problems associated with the conventionally designed building, difficult to justify robot employment economically and several managerial barriers. The present paper reviews the existing applications of building robotics and assess their implementation in practice.

***KEY WORDS**: Robots, Construction, Automation, Construction Industry, Building construction.*

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I INTRODUCTION

The construction industry is one of the critical sectors of the economy and is a major customer of the manufacturing, transportation and service sectors. All the areas which are directly and indirectly related with the construction industry are open for automation and robotic applications. There is a shortage of 600 million dwelling units through out the world. India produces 3.3 million housing units per year, which is far less than the requirement in India's tenth plan.
Robotic systems are initially developed to reduce labor requirements, shorten construction time, reduce cost, and improve quality. Robots typically work faster than humans and do not suffer from fatigue and high quality is maintained. Since, quality is maintained there will be less possibility of future problems. Robots can be used in the difficult terrains and places where workingmen are exposed to dust.
Robot is a machine which performs different tasks given by the programmer. Technically Robot can be defined as a re-programmable, multi functional manipulator, designed to move materials, parts, tools, specialized devices, through variable programmed motions for the performance of a variety of tasks
In construction industry, there is the need of different kinds of robots. Construction robots must travel to the workplace and must move about the site because buildings are stationary and of large size, and they require engines, batteries, motors to drive themselves. So, the key requirement is the ability to move successfully from one work location to another. Therefore, construction robots require digital control with manipulators using co-ordinate systems to direct three-dimensional motion.

Hindrances
The following are the major barriers for construction automation and robotics:

- Existing robots are not well
  adapted to building construction.

- Problems associated with the conventional design of building.
- Difficult to justify robot employment economically.
- Managerial barriers.
- The developments made at job sites are not suitable for other works.
- No horizontal diffusion of knowledge between competing companies; therefore, each company has to invest all the development costs, making its development more cost effective.
- Equipment-leasing companies are reluctant to add construction robots to their line of business due to lack of qualified technical supporting staff .
- Insufficient development of construction robot prototypes.
- Nature of construction work, and
- Unsuitable Building Design.

The reason for the failure to implement, involves the adaptability of robots due to the building design. The design must enable the robot to move freely and perform its work with in the designated location of walls and partitions. It must also allow easy movement between works in terms of passage through doors and convenient transfer of the robot between floors and buildings. All locations that cannot be accessed by a robot within these constraints have to be completed by a human worker with more or less conventional methods.

Research funding is another barrier, which plays a major role in the development side. If the management is ready to encourage innovations through funding, the construction automation can be efficiently implemented. The economics of robotized construction ultimately determine its viability as a realistic alternative to the conventional building methods.

Robots are not being used because of their high cost. The costs of robotized construction include the direct (product related) and indirect (time related) cost of the robot, cost of the operator who supervises the robotized work, and cost of adaptation and modification of the construction method in view of the robotic applications.

The objective of the paper is to review the existing applications of building robotics and assess their implementation in practice and to bring awareness among the people about automation and robotics. Construction industry, in general, has been traditionally conservative in accepting new approaches. By encouraging the innovative ideas, through research funding the construction industry can step forward in the technological competition. So, new ideas are needed to be encouraged and should come across the barriers for its implementation.

II LITERATURE REVIEW

Lynch (1993) states that, there is an emphasis in transferring the advanced robotics technology to the civilian sector. Whittaker and Bandari reported that “Robots were emerging in construction as a way to increase productivity, improve quality, and decrease hazard to human workers. Skibniewski and Russell (1989) stated that “with less optimistic estimates for construction robotics due to their complex operational environments, it can be anticipated that their application can result in approximately 10-15% increase in overall construction productivity rate.”

Thompson states that development of robotic systems for construction application has advanced dramatically over the past few years. Warszawski (1990) divided the developed construction robots into four categories. Tucker (1988) computes the “automation potential” of 17 “distinct areas.” Kangari and Halpin (1989) rank 33 processes according to need, technology and economics, to arrive at “robotics feasibility” score.

Furthermore, working in the construction industry can be an extremely dangerous occupation. MacCollum (1995) describes that the construction worker is five times more likely to be killed on the job than other workers. Bares (1999) stated that robots can perform many of the more dangerous work operations without risk. Nestle (1999) gives an example that workers can remain on the floor below as robots spray polyurethane foam roofing materials to seal the structure above.

Winston (2000) explains that the U.S construction industry concerned about the lack of skilled personnel. Moreover, the current workforce is aging at a rapid rate. Many young people today consider construction work is dirty and undesirable. Thus, draining labour pool should result in automation and robotics.

Applications of Robots in Building Construction

- ***Exterior handling robots***, which are employed in handling large loads such as concrete buckets, prefabricated elements, and steel bars. These robots have a configuration similar to mobile cranes.
- ***Horizontal finishers***, which are used for finishing floor surfaces like smoothing, trowelling etc; these have a work tool mounted on a horizontally moving carriage.
- ***Vertical finishers***, which are used for finishing like painting or inspecting exterior walls. These robots have a work tool mounted on vertically moving carriage.
- ***Interior finishers***, which are used for various finishing and material handling tasks inside the building like painting masonry etc. Usually these robots have anthromorphic configuration.

Bridge Painting

The development of a robotic paint system is justified by the potential improvements in safety, quality and productivity. In addition, the painting quality will improve, and a worker does not suffer from exhaustion or fatigue. The minimum thickness of the paint should be satisfied which can be achieved by robotic bridge painting system. Paint on steel bridge is applied in a series of coats ranging from 0.025-0.15 mm.

Culvert clean-out and Inspection

The main culvert cleaning technique is manual cleaning and some times assisted by high pressure water and vacuum systems. Many robotic systems exist to inspect interior of pipes and drainage conduits and to detect voids around sewers and under offshore pipelines.

Inspection ideas focused on three technologies- optical, sound, and radar. The optical techniques include laser profiling scanners and video cameras. The sound techniques considered were ultrasonic for interior wall inspection and wall tapping techniques for through the wall inspections. Audible techniques may also work to determine whether a culvert is full of debris. Ground penetrating radar, however, was viewed as a method to investigate, because ground penetrating radar systems are well developed and commercially available.

Drilled-shaft Inspection and Measurement

Regardless of the shaft diameter, it is considered unsafe for a human inspector to descent into the shaft, unless the shaft is cased. Visual device using a mirror and sunlight is the major inspection technique. Inspections are performed from the top of the hole or by lowering man into the hole. Some use video equipment to examine the shaft. For slurry filled shafts, sensors other than video are required. A robotic excavator for slurry filled foundation excavation that uses ultra sonic sensors to determine the location of the walls and a computer to guide an excavator is under development. For slurry filled holes sonar is suggested..

Placement and Retrieval of Traffic cones

With the increasing rate of work zone accidents, there is more interest in automating some functions to reduce the number of workers exposed to hazardous situations such as placing and retrieving traffic cone. Since semi automated devices do exist, the technology experts' primary suggestion for placing and retrieving traffic cones is to evaluate current traffic cone machines. Robotics has also been introduced in many works like Non-destructive testing of roadway materials during construction, underwater structure inspection for scour and corrosion, luminaire and traffic signal-bulb replacement etc.

Case Study

A multistory building is considered for the application of robotics in building construction. In this case study the adaptation of robotics are considered for plastering work. The study has been done by comparing the cost and time of the work actually done (plastering) by conventional method and with the robot projected values of cost and time.

For walls: Plastering of 20 mm thick in CM (1:6) and CM (1:4) for 1^{st} and 2^{nd} coat respectively with dubara sponge finishing including making 12 mm / 12mm grooves in either side of the column and beams. This includes cost and conveyance of all materials to side curing, scaffolding charges and all incidental and operational charges etc.

For ceiling: Ceiling plastering of 12 mm thick in CM (1:5) and CM (1:3) for 1^{st} and 2^{nd} coat respectively with dubara sponge finishing including cost and conveyance of all materials to site, curing, scaffolding charges and all incidental and operational charges etc.

Cost of installation of the robot on the building site:
The cost per hour is identified using following

C= (P * Pr (I, n) + Cm) / H + Co.
where P = Investment on robot including cost of carrying, effetors sensors and other adaptations.
Pr (I, n) = Capital recovery factor (depreciation and interest factor, assuming annual interest 'I' and economical life 'n' in years.
C_m = Cost of repairs and high level maintenance of the robot per year.
C_o = Operating cost (including some weather effected parts) per hour, and
H = Number of robot employment hour /year.

Table 1. Comparison between Robotic system and Conventional system

Type of System	Job	Plastering Area in Sq. m.	Cost (Lacs) & Time (Days)
Conv. system	Plastering	12869.31	10.97 92
Robotic System	Plastering	12869.31	4.14 12
Savings	------	-----	6.82 80

III DISCUSSIONS

From the above case study the cost can be saved up to 62 % and time can be saved up to 85 %. In the highly conservative construction sectors technological innovations are always viewed with a certain measure of distrust. The economic productivity gains must be very significant in order to convince the prospective user. These economic benefits and intangible benefits are associated with productivity gains relative to manual labor. In some developed countries like Japan and America availability of labor is a major problem and the adaptation of construction automation will be beneficial. Even the situations dealing with dirty areas like drainage, work can be done with the help of robots. These are the tangible benefits. Intangible benefits are those which include improved safety, higher quality and dependability. Ultimately, the success of robotized construction will depend on the support it receives from the project management.

IV CONCLUSIONS

The following conclusions are drawn based on the above work:

- The Construction industry demands a productivity increase by means of automation& robotics.
- Robust, safety, durability and qualitative factors should be given priority in construction industry.
- Robotization reduces the construction time, cost, time, and efforts.
- The case study reveals that the cost of the work plastering can be saved up to 62% by using robotic system in comparing with manual system.
- The time can be reduced from 92 days to 12 days, thus contributing the major saving in labour cost with no accidents or injuries to the labour force relating to plastering work.
- Architects and engineers need to advocate standardized design that allow for easier automation.

In order for construction automation with robots to be fully operational, designers must try to simplify designs as much as possible relating to repetitiveness and standardization of components.

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