ROBOTICS AND AUTOMATION IN CONSTRUCTION INDUSTRY

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ABSTRACT: The construction industries are facing problems of productivity, quality of work, safety, and the completion of projects in time. In construction industry a worker is exposed to hazardous environment, and has to do more physical work, effecting his health and also productivity. The automation and robotics can offer solution to many problems of the industry. In the past the major barrier to construction automation is the lack of electronic components and systems. This is solved now with the development of information technology, and the current obstacle is the high cost of automated systems, shortage of public money for R&D, and problems of acceptance. The robots employed in construction have followed the same concept as those employed in manufacturing. However, construction industry requires a different kind of robot compared to manufacturing Industry. The robots are stationery and product moves along the assembly line in manufacturing sector, but construction robots have to move about the site because buildings are stationary and of large size. The construction robots must function in adverse weather conditions, including variation in humidity, and temperature and increase the overall construction productivity rate. The major objective of the paper is to review the existing applications of building robots and to assess their implementation in building industry. A case study is considered for the implementation of robots for the painting work of the University Building at Saifabad PG College of Science, Hyderabad, India.

Key words: Automation, robotics, construction industry, and productivity.

1. INTRODUCTION

The construction industries are facing problems of productivity, quality of work, safety and timely compe-tion of projects in time. In construction industry, worker is exposed to hazardous environment and has to do more physical work, effecting his health and productivity (Srinivas and Kumar 2004). The automation and robotics can offer solution to the above problems of the industry.

The robots are advanced automation and remote control devices used on the construction site. It is defined as a reprogrammable, multifunctional, designed to move material, parts, tools or specialized devices through variable programmed motions for the performance of variety of tasks. Construction robots are ingenious machnes and use intelligent control with variation in sophistication. The provision to increase speed and accuracy is incorporated in the design of robots.

2. CURRENT STATUS

Construction automation is growing and becoming a practical and attractive technology. Presently, overall automation and robotics stems mainly from the availability of research money and is not driven by the needs of industry. Construction research is funded at a level much less than 1% of gross sales, where as other industries funding levels are in the range of 3% or more. But the demands for housing needs are 1.2 billion between now and 2050. Further construction managers, craft workers, and the industry demands are conflicting with each other.

Adaptation of new technology is determined by technology push, and demand pull. Almost all the robots in some use today are either material handling robots or floor finishing ones. Most of the robots are operated under direct continuous human control. Many prototype field robots are developed, but only few are used in the construction industry. The reasons are as follows:

- lack of appropriate building sites,
- lack of economic justification,
- lack of interest of the company's management,
- availability of better equipment for the same function,
- conservatism of potential users, and
- problems with material supply.

The process of disseminating the early results from research and development of construction automation and robotics into industry is now slowly taking place Murthy et al. 2004). A number of prototypes have been designed and built for construction industry. The robots are emerging in construction to increase productivity, improve quality, and decrease hazards to human workers. The application of robots results in approximately 10 – 15% increase in overall construction productivity rate.

The major objective of the study is to review the existing applications of building robots and to assess their implementation in building industry. A case study is considered for the implementation of robots for the painting work. Comparison has been made with the current analysis and with the projected information using robots.

3. STATUS OF LITERATURE

Automation and robotics in the construction Industry has advanced dramatically over the past few years. Robotics systems were initially developed to reduce labour requirement, shorten construction time, reduce cost and improve quality.

Skibriewshi and Hendrickleson (1998) reported that the application of surface coating is very much suitable for robotics. Tasks of this type lend themselves to robot application, because they are labour intensive, and consist of simple repetitive motions. Robotics surface painting research has been carried out by several Universities and Industries throughout the world. Kumagai Gumi Lt., Tokyo, Japan has developed the surface finishing robot for walls (Tokioka et al. 1989). It is an independent unit to which various process modules can be attached for blasting, painting and inspection. The robot is capable of covering from 45 – 50 m^2 / hour.

Moon and Bernold (1995) at North Carolina state University developed a robotic Bridge paint removal system. The purpose of the system is to provide safe working environment during bridge paint removal operation.

Amarjit Singh (2005) reported the world housing needs till 2050 as 1.2 billion units and world construction sector has to construct one house for every 0.28 second, which can be achieved only with use of robotics in construction. He mentioned architectural flexibility is attainable with standardizing modular floor plans.

Zhou (1991) described that 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 cones. One semi automated cone machine and a fully automated cone placing and retrieving system has been developed for hazardous situations.

Crawford (1988) mentioned that inspection ideas are focused on three technologies -optical, sound and radar. The optical techniques included laser profiling scanners and video cameras. Laser profiling would yield a more quantitative result while the video systems offer a more user-friendly but more qualitative solution. The main disadvantage of optical techniques is their inability to examine the soil conditions behind the culvert walls. The sound techniques considered were ultrasonic for interior wall inspection and wall tapping techniques through the wall inspections. Ground penetrating radar systems are well developed and commercially available. Audible techniques may also work to determine whether a culvert is full of debris.

In general the construction industry has been traditionally conservative in accepting new approaches. This paper makes an attempt to use the robotics in building industry.

4. ROBOTS IN CONSTRUCTION INDUSTRY

In construction industry workers are exposed to unhealthy environments such as working in severe hot weather conditions, constant fear of fall from height, the fear of accident in working for any repairs, and exposed to dust and dirt for concrete ready mix plant/crusher plant. All these conditions, effect the efficiency of worker, accordingly production rate will reduce and consume more time to complete the projects.

Hence there is an urge and search in the engineering community to find the solutions to the above mentioned problems. In construction automation and robotics, there is hope and solution to the above problems. In view of these, through out the world research is being done in construction automation and robotics, which resulted in finding the following successful robotic applications in Civil Engineering field. The following are the various robots used in the construction Industry.

4.1 Autonomous plastering robot

This is the first plastering robot prototype. It has successfully plastered the walls at actual building sites and is shown in Fig.1.

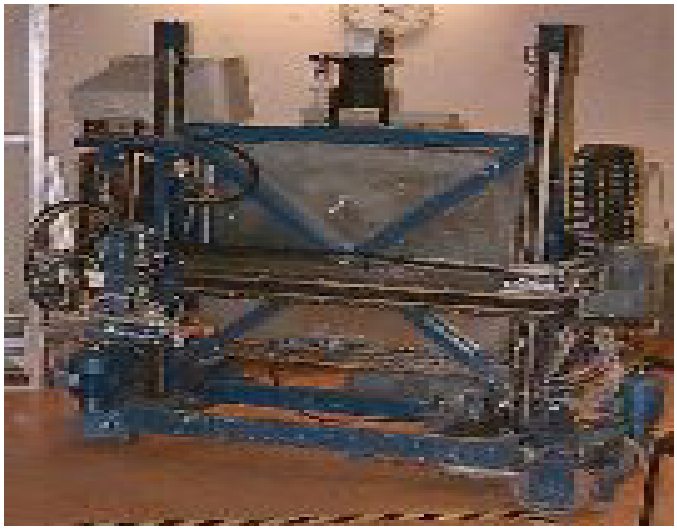

Fig. 1. Autonomous Plastering robot

5. DEMOLITION ROBOT

It is used in the confined space and selective demolition works. The precise control enables demolition for needed sections, while leaving the remaining sections unscatterd and is shown in Fig.2.

Fig. 2. Demolition Robot

5.1 Robot for cement industry

It is employed for stripping of linings and cleaning kilns even before the kiln is completely cooled down and is shown in Fig. 3.

Fig. 3. Robot for cement industry

5.2 Case study

Construction of a building for Computer Mathematics, Physics & Chemistry Departments, (G.F. FF & SF) in the premises of P.G. College of Science, Saifabad, Osmania University, Hyderabad, India is considered to demonstrate the applicability of robots for building automation. The estimated cost of the building is $202400.

The robot proposed for the case study is for painting work and also can be used for several building tasks, with higher rate of utilization over its economic life and simpler maintenance and operating procedures. It is designated as GMF – 700. It has six degrees of freedom with a reach of 1.62 m. The robot employed is with a continuous human involvement. It should be always supervised by a human operator and a helper to assist in setup, transfers, movement between work areas and for identification of special features of the environment. Consequently the cost of robotic system includes the cost of robot and wages of one operator and one helper (Non-skilled).

The objective is to identify the cost and time elements for the painting work of the building i.e., external and internal painting. The net painting areas have been calculated duly deducting the structural glazing areas. Finally the comparison is made between the traditional method and execution with the robot.

5.3 Robot hire charges

The cost of hiring robot includes depreciation, interest on investment, maintenance, and operating expresses. The cost per one hour "C" can be calculated from the following equation.

$$C = \frac{P(P_r(i,n) + C_m}{H} + C_o$$

Where
P = Investment in the robot , i.e. US $130,000
$P_r(i+n)$ = Capital recovery factor (depreciation and interest) assuming annual interest i and economic life *n* (in years)
C_m = Cost of repairs and maintenance of robot per year
C_o = Operating cost $2 per hour (include wear affected parts)
H = number of robot employment hours per year

5.4 Specifications for External and Internal Painting

Snowcem/cement paint (water proof painting) to external faces of walls using approved colour/shade/make including primer coat (total 3 coats) has been specified and cost and conveyance of all materials & labour charges are included in the painting cost. As per standard rates approved by Public Works Department of Government of Andhra Pradesh, India is $14 per 10 sq. m. is considered for external painting work.

5.5 Internal painting

Oil bound distemper for walls with 3 coats including primary coat has been specified using approved brand/colour/shade and cost and conveyance of all materials & labour charges are included in the painting cost. As per the standard calculation $9 per10 sq. .m. is considered for internal painting work.

Cost analysis for external and internal painting is shown in Table 1 for conventional and robotic method.

Table 1. Cost Analysis for Conventional and Robotic

Conventional Method			With Robot	
Sl. No	**Description**	**Cost ($)**	**Description**	**Cost ($)**
1.	Internal painting (Excluding materials cost)	2657	Internal painting with Robot	3301
		12267		**4401**

Table 2. The Time Schedules for External Painting

Sl.No.	**Conventional Method**		**With Robot**	
	Description	**No. of Days**		**No. of days**
1	Erection of scaffolding	12	Erection of Robot	3
2	Painting work for external area for 1504 Sq. m.	20	Painting work for external area for 1504 Sq. m.	5
3	Removal of Scaffolding	5	Removing Robot	1
		37		**9**

Table 3. The Time Schedules for Internal Painting

Sl.No.	**Conventional Method**		**With Robot**	
1	Internal painting for 4435 sq. m.	30 days	Erection of Robot Painting with Robot Removal of Robot	3 days 13 days 1day
		30 days		**17days**

The time schedule for external and internal painting is calculated and is shown in Table 2 and 3

6. DISCUSSIONS

Based on the above analysis the cost of painting for external and internal using the conventional method is $12,267 with in 67 days. The same quantity of work can be achieved for $4,401 within 26 days using Robots. The percentage cost of saving is 64% using Robots. In addition, the study suggests that the robotic painting to external faces is more economical.

7. CONCLUSIONS

The construction industry is traditionally conservative and there are conflicting interests of engineers, owners, and workers to implement construction automation and robotics. Robotic systems are initially developed to reduce labour requirement, shorten construction time, reduce cost, and improve quality. There are several human barriers for the implementation of automation and robotics including fear of unknown charges, perception of threat of losing jobs or skills, fear of inability to handle new system and

inadequate understanding of the need for change. Based on the research work the following conclusions are drawn :

- The cost of painting work by Robotics is $4,401 and cost of painting by conventional method is $12,267 thus saving of 64%.
- The time schedule for painting by Robotics is 26 days and the time schedule for painting by conventional method is 67 days.
- The robotic painting is economical than conventional method.
- The application of robotic painting to external faces is more economical than internal painting.
- Robotization of building tasks is an important element of an integrated and automated building realization system.
- Even though the initial cost of robot is high, the cost of robotization may be decreased by applying to various projects.

In view of the above it is desirable to apply construction automation in building industry for other areas of activities i.e., plastering work, brick laying, flooring work etc., by nurturing necessary research and development in construction automation. If automation and robotics is perceived to improve high quality, lower cost at faster speed than conventional method, besides improving job security, wages, safety and work conditions, then workers and society will demand construction automation and robotics in near future.

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