Robotics in Civil Engineering

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Abstract

A robot is a reprogrammable, multifunctional manipulator designed to move materials, parts, tools or specialized devices through variable programmed motions for the performance of variety of tasks. It is an autonomous machine that is capable of mobility, dealing with large forces, harsh environment and is equipped with some cognitive skills. Robotics is the science of designing, building and using robots. It is the physical extension of computer technology. The greatest incentive for robotisation on construction sites is in the cost of labour, of meeting environmental, safety and health regulations and avoidance of disruptive effects of strikes. These machines perform high-volume, simple and repetitive tasks most economically. The robot requirements for construction tasks and its applications are in inspection, maintenance, spraying, cleaning, welding, tunneling, demolition, site clearance, underwater work and nuclear plant construction are reviewed in this paper.

Keywords
robotics, maintenance, demolition, tunneling, inspection.

I. INTRODUCTION

Computer technology is already assisting the construction industry in many areas, notably in computer aided design, knowledge-based design, communication, scheduling and financial control. Robotics is the only area of this technology that has not significantly penetrated the industry, because of high level of investment required. However, introduction of robots in construction industry to avoid ever-rising accidents in hazardous operations is justifiable. It is reasonable to expect financial benefits from machine capable of working in foul weather, darkness and hazardous areas without problems of motivation and administration. The use of robots in the automotive industry is widespread due to repetitive operations to be carried out in the industry. The introduction of robotic technology into the construction industry is slow because of slow mobility and lack of manipulation tools. Technical problems associated with the application of robotics are being solved and the comprehensive range of mobility, vision and manipulation tools maybe expected by the end of twentieth century. The extensive research and development activities are in progress on various aspects of robots in developed countries. The task flexibility of robotic mechanism can be increased with increase in degree of freedom. The three basic degrees of freedom are pitch, yaw and roll or stretch (1, 3, 4) which are similar to actions of fingers, arms or legs and required to be incorporated in robotic devices to make them more efficient and suitable for various applications in the construction industry.

The principal advantage of robots lies in the remote operations which are tele operations by human is a principle likely to be adopted for the construction sites where the plant in dangerous situations maybe controlled by an operator situated safely away from the hazard. Laser and fiber optic technologies are a paramount importance in the teleoperations and to assist the microcomputer for the data transmission. Tele robotics is such a technology which is a mixture of two technologies where a computer is programmed and constrained to carry out certain simple repetitive tasks, leaving the operator to attend to the main control. The computer aids are becoming more and more sophisticated, including models of the physical task and advisory aids based on the expert system. This paper

reviews the requirements and the applications of robots in construction industry for construction tasks.

II. THE ROBOT REQUIREMENTS FOR CONSTRUCTION TASKS

- It should work in hazardous situations to replace men from fatalities.
- It should work in foul weather, darkness, hazardous areas without problems of motivation and administration leading to financial benefits.
- It should be designed to maximize benefits in number of application areas.
- It should be autonomous, mobile and cognitive.

III. CRITICAL CHARACTERISTICS REQUIRED FOR CONSTRUCTION ROBOTS

These features include:

Sensing and control, mobility and manipulation, human factors and task factors, expert system and task flexibility. These features are discussed as below.

A. Sensing and Control

The biggest problem in development of robots for construction lies in the sensing and control, particularly in location and navigation. For control, the mobile robot constantly needs position and heading information. Obstacle avoidance and object location will be possible with the use of video and image recognition techniques. Present robots for construction, use prelaid guidance tracks. Obstacle avoidance by use of touch sensors and ultrasonic is in use on several prototypes.

B. Mobility and Manipulation

Equipment mobility on construction sites depends on several factors such as varying surface materials, type of tasks/jobs to be carried out and type of working space. Rail-mounted robots have sufficient mobility for many finishing operations and wall inspection tasks. Manipulative tasks will be divided among various robots classified by their load carrying capacity, length of arm and type of grip.

C. Human and Task Factors

Safety is the primary reason for developing construction robots to work in harsh environments, high and deep places, boiler-seas, and in radiation zones. In these applications, the robots could work alone or a tele robot could work remotely with its operator in a place of safety. For safety reasons, either man or machine must have overall control. To avoid the delay problems in difficult tasks and feedback of manipulation to the operator, it is relevant to consider the current state of telecontrol.

Human factors are especially important in tele operation. Automation decreases manual workloads, but increases cognitive and mental work. The man-machine interface is very in control and display of machine.

D. Expert System and Task Flexibility

Robotics alone will bring little benefit to the construction industry. Only with total organization of the construction process will real progress be made. For civil engineering applications, expert systems, CAD/CAM and database technology are very important in robotics for task flexibility. The intensive research work in this direction on new languages, programming environment, engineering graphics, logic, calculation and control requirements is in progress (1, 2, 3). The development of expert system depends on the loadings, material properties, components, connectors, assembly, and geometric reasoning system for representation of the construction components in three dimensional space. A computerized work-control system for robotic work will be essential for their optimal use; this would have to include site organization and sophisticated handling of materials from factory to robot.

IV. APPLICATIONS

The diverse applications currently envisaged are given below:

A. Assembly-manipulation-joining

The area of highest economic benefit of robotisation is the building industry is that of the structural system, which the single largest component is. A range of devices exist for concrete handling – placement, screeding, and finishing. For mechanical handling there are manipulative devices for panels and wall boards. Other applications include prefabricated assemblies and structural welding, robotic devices in this area as follows:

- Auto clamp for steel beam and column erection to avoid dangerous manual operations at heights.
- Playback controlled robots for large construction projects such as dams and power stations.
- Wall board manipulators to grab boards by suction-pads and to get in position.
- Remote controlled load carrier with the ability to climb stairs.
- Concrete distributor for concrete placement and collision avoidance of columns.
- Concrete placement manipulators for concrete encasement work for nuclear plants and radiation zones.
- Formwork sliding systems with level sensors and motion controllers for bridge piers and dams can be used without workers for mounting the forms.

B. Inspection-maintenance-survey:

The repetitive nature of building inspection, large requirement for building maintenance and sit survey to locate the buried services by sensing could be successfully performed with the help[of robots. Robotic devices currently reported include the following:

- Wall tile inspection using climbing robot with ultrasonic testing facility without access to scaffolding.
- R/C wall inspection robot: Tests for weathering and structural faults using ultrasonic and video equipments.
- Soil Under water inspection compaction test robot for roads and site preparation which is provided with radiation back scattering to measure compaction and gyro navigation for position measuring. Works within marked boundaries autonomously.
- Under water inspection: Tele robots for offshore industry is provided with under water manipulator, computer with tele manipulator and T.V. cameras, all mounted on the robot. Video processing is used to obtain 3D coordinates and reconstruction of geometric elements is performed automatically.

C. Spraying- Finishing-Cleaning

The various spraying operations in construction work are suited to robotic manipulators. The coating of high buildings, application of fire proofing and shot blasting should be performed without human operator from the work place. A range of applications from cleaning to sand blasting could be successfully carried out with the help of robot. The robotic devices are:

- Wall painting robots for high rise buildings .It is provided with automated spraying equipment and surface preparation capability of shot blasting,
- Ceiling painting: With spray compressor and navigation control computer on as mobile platform.
- Fireproofing spray robot with electromagnetic and ultrasonic sensing to measure spray range.
- Cleaning robot
- Wall coating delamination robot: Climbs on cable, carries delamination of wall coating by water jet spray at high elevations without out the need of scaffoldings.
- Concrete floor finishing and screeding mobile construction robots. They are provided with contrarotating steel paddle trowels and can be programmed to carry out floor finishing autonomously using gyrocompass and distance sensors for navigation .The floor screeding robot carry out levelling of freshly poured concrete using tampering bars automatically.

D. Tunneling

Conventional surveying is highly labour intensive and requires cessation of tunneling. Due to the hostile working environment and shortage of skilled workers, the total automation of shield tunneling using feedback of data from auto survey instruments is possible. The various operations to be performed by robots include the erection of lining segments to concrete spraying for small bore as required for communications and services. The robotic devices in this area are as follows:

- Auto surveying devices for shield tunneling. It is provided with video and electronic distomat and uses fibre optic cable to transmit data to microcomputer and laser source for setting shield machine.
- Shield segment erection: to erect and position the heavy ring segments. It is performed with the help of DOF manipulator mounted on the shield machine using location measurement optical sensors.
- Small bore automatic shield tunneler: It is intended for the installation of small diameter conduit tunnels without digging up road surfaces. An automated lining system cast rings of quick setting resin mortar in situ. The whole process including transport of materials in controlled by computer at the surface which communicates by fibre optics.
- Concrete spray for tunnel lining. R/C lining instead of steel lining for rock tunnels is sprayed by a manipulator mounted on crawler excavator. Playback techniques are used to control the spray motion and using distance sensors, the coating thickness is built up from the bedrock surface to the required profile.

E. Miscellaneous applications

This group of construction robots for miscellaneous applications is mainly concerned with operations in difficult environments where man cannot work. Such areas include nuclear power station, decommissioning problems, deep sea oil prospecting etc. Robotic devices with respect to above applications are given below:

- Demolition and site clearance robots: It is integrated with a digital photogrammetric system for management of large earth works projects. These are remote controlled devices with radar beacons for location, radar sensors for obstacle avoidance and microwave communications, capable of long range obstacles sensing, control up to 2km range and capability of controlling up to 100 units on the same site.
- Nuclear plant construction: The servicing and eventual decommissioning of nuclear installations is totally reliant on the use of robots and tele robots. This devices perform the operations like cutting out and lifting of floor sections to remove the radiation damaged power cables. The heavy cutting robots for demolition of nuclear power stations. Abrasive jet cutting is employed to minimize demolition dust.

CONCLUSION

Robotics is the area of computer technology which is now penetrating the construction industry. Robotisation of construction sites is very important to replace men for hazardous operations in foul weather, darkness, deep waters, high radiation zones, hazardous areas and at high elevations.

It is also useful from the point of view of avoidance of disruptive effects of strikes, problems of motivation and administration, safety and health regulations, shortage of skilled labours and to carry out repetitive, dirty and dangerous works and completion of projects or tasks with quality control, within the specified time and economy.

Though this technology is assisting the construction industry in developed and developing countries, considerable research is required for sensing and control, human factors, task flexibility and the software support to integrate robots into an overall computer aided design and data based construction management.

Robot requirements for construction tasks and various applications of robots in construction industry depending upon the nature of work to be performed are presented in this paper.

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