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Feasibility of Robotics in Construction

Emploi de la robotique dans l'industrie de la construction

Anwendungsmöglichkeiten von Robotern im Bauwesen

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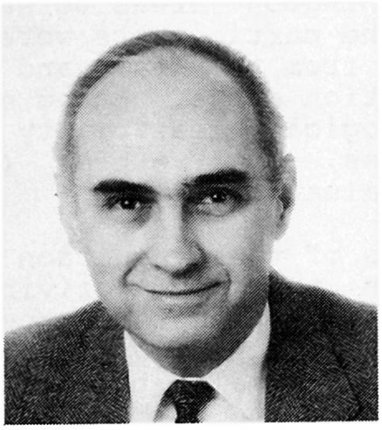

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SUMMARY
This report examines issues which relate to the feasibility of using robotics in the construction industry. Major factors influencing this topic include need for automation, technological feasibility, and the economics of implementation.

RÉSUMÉ
Cet article traite de l'emploi de la robotique dans l'industrie de la construction. Les facteurs principaux concernent le besoin d'automation, les possibilités technologiques et les aspects économiques.

ZUSAMMENFASSUNG
In diesem Referat werden Themen der Automatisierung von Bauprozessen und die Anwendung von Robotern in der Bauindustrie behandelt.

1. INTRODUCTION

This paper presents some conclusions based on a study into the feasibility of using robotics in the construction industry. In the course of the study, the importance of data integration to support automated devices became apparent. In order to concentrate on processes which have potential and exclude those processes which are not strong candidates for automation, brainstorming sessions were held with contractors in the Atlanta and Washington areas to select processes for further evaluation. The participants were asked to consider construction processes from the heavy and highway, building, and industrial construction areas. Based on an evaluation of the need and technological feasibility of automating or robotizing each process, thirty-three (33) processes were selected for careful evaluation.

One of the premises of the evaluation of each of the 33 selected processes was that the driving force supporting robotization of a production process is the need and economic feasibility of the robotization. Counterbalancing this need, however, is the technological state of the art which can either support or present formidable barriers to the automation.

2. CHARACTERISTICS OF TECHNOLOGICAL FEASIBILITY

Certain processes rank as highly feasible from a technological point of view because of special characteristics. They are processes which are related to processing of surface areas (e.g. sandblasting, bushhammering, concrete finishing) and either require no material application (e.g. concrete finishing, bushhammering) or have to do with the application of a fluid or semi-fluid material (e.g. sandblasting, shotcreting). On the other hand, those processes which rank low in technological feasibility require complex operations involving the movement, attachment, etc. of solid components or objects to a fairly high level of precision (e.g. plumbing, structural precast).

Although automation to increase worker productivity is possible in such processes as forming or plumbing, the level of technology in sensors, artificial intelligence, and allied areas is not presently available to support closed loop automation of such activities. Notwithstanding the fact that Japanese firms such as Kajima report the development of reinforcing steel placement "robots," these are devices with local end-of-arm tooling automation requiring continuous human monitoring. They are not true robots in the sense of the closed loop definition of a robot (i.e. no human intervention required).

3. ROBOTIZATION BASED ON DANGEROUS ENVIRONMENTS

Unsafe and hazardous environments provide the economic/need rationale for application of robotics in construction. A typical example of this is the teleoperated Remote Reconnaissance Vehicle (RRV) developed at Carnegie-Mellon University for work in the clean up of the Three Mile Island reactor building. Another application related to construction which may drive the advance of semi-automation or teleoperation of earthmoving equipment is the large amount of funding available to clean up toxic waste dumps. Large companies such as Bechtel are actively seeking methods of remotely controlling loaders and trucks. Presently equipment operators involved in these clean up activities are subjected to dangerous chemicals and pollutants. Although operators wear protective clothing, the long term effects of this activity are not clear and removing the human operator from this dangerous work is considered to be an urgent priority.

4. NEED BASED ROBOTIZATION

Examination of the processes which rank high based on the needs criterion confirms the assertion that dangerous or unhealthy process environments provide an important basis for robotization. Those processes (of the 33 reviewed) with high rankings for need include:

(1) Bush Hammering
(2) Concrete Placement
(3) Drywall Installation
(4) Painting
(5) Tunneling
(6) Wall Finishing
(7) Sandblasting

The tunneling processes place workers at risk due to the multitude of imponderables associated with sub-surface construction. Cave-ins, toxic fumes and gases, and similar unhealthy or dangerous aspects contribute to an environment in which the human exposure to hazard is very high. Bush hammering, sandblasting, painting, and wall finishing (to include drywall installation) generate dust or toxic fumes which are unpleasant and hazardous to the health of the worker.

Other highly ranked processes based on the need criterion although not associated with particularly unhealthy or dangerous environments, are candidates for automation due to labor intensity or repetition.

Need must be sufficient to offset any technological obstacles to automation or robotization. In effect, the economics of robotization are driven by one or a combination of need categories. For technically complex situations, the need must result in such large economic benefits that the payoff is sufficient to offset the large developmental and market penetration costs. One process which was not addressed in the set of 33 and which promises such a large payoff is industrial piping. It is estimated that up to 40% of the costs of industrial plants (e.g. petro-chemical, power generating, etc.) are tied to piping. Such plants range in value up to 1 to 2 billion dollars for nuclear power or large fossil fuel plants. This would indicate that between 300 to 400 million dollars may be tied up in piping on a billion dollar industrial plant. A savings in the fabrication or installation of piping amounting to 5% would yield a significant reduction in plant cost.

For this reason, economic benefits associated with improved production and quality on large industrial plants may support robotization for processes which are weak candidates based purely on the hazardous environment criterion. The best example of this economic benefit driving automation developments is the induction bending of industrial piping to reduce welds and increase productivity and quality. For processes which contribute significantly to the overall cost of a construction project, automation to reduce skilled labor requirements and increase productivity and quality will often support developmental costs.

For this reason, partial automation of concrete, piping, and earthmoving operations may be justified from an economic point of view. Particularly, the ability of a robot or automated technique to reduce the required skill level while maintaining or improving the required level of quality will offset the costs of developing supporting technology. The use of lasers to achieve semi-automation of heavy equipment has been widely reported. Automation breakthroughs which improve the rate of placement and quality of concrete, both in the precasting plant and on the site, can be expected to support the investment required to achieve semi- or full-automation.

5. ROBOTICS FOR INSPECTION TASKS

One area of robotics application in construction which was not considered directly in the 33 processes selected for analysis is the area of construction inspection. The initial brainstorming concentrated on processes which were production oriented. Although not production oriented, inspection by automated devices in many cases seems to exhibit the need, technological, and economic characteristics which justify robotization. In some cases, inspection activities must be carried out in dangerous or difficult to reach locations.

For instance, inspections of augured piles or caissons to determine whether the required bearing strata has been reached place human inspectors in dangerous situations. Often the inspector is required to descend into the pile casing to determine the characteristics of the substrata. Toxic gases may be encountered. Automated devices can be used to develop the required information using sensors.

Tile inspection devices to check the bonding of tiles to large vertical surfaces in buildings have been developed in Japan. Inspections of suspension or post-tensioning cables on bridges could be conducted on a continuing basis by robot like devices. Similar inspections in drains, channels, pipelines both above and below grade could be accomplished by semi-intelligent devices. Inspections of large tanks offer a similar opportunity. Many inspections of this type are both tedious and performed in a dangerous environment. Further they are of a continuous nature and commit the human inspector to boring and dangerous work for extended periods of time.

It would appear that the development of inspection robots would be a cost effective application of existing technology to the needs of the construction industry. Research in the development of such semi-intelligent robots would provide a base of information regarding the problems involved in developing more sophisticated production robots.

6. SUMMARY

Several points appear to be central to the development of robots for the construction industry based on the research to date.

(1) Tasks which require assembly and installation of objects (particularly heavy prismatic solids) are not feasible using the present robotics technology.

(2) Tasks which involve the application of fluids or fluid like materials are better adapted to the material handling capabilities of existing robotics technology.

(3) Construction activities related to the preparation or processing of large surfaces are well adapted to construction automation. Particularly, when no material must be applied to the surface to be processed (e.g. bush hammering, concrete finishing), robotics can be applied.

(4) Inspection tasks appear to be well adapted to automation and robotization.

(5) Operations in unsafe environments offer excellent opportunities to apply robotics or teleoperation. Economics and worker safety considerations support significant developmental investment to robotize unsafe and dangerous work processes.

(6) The application of robotics to processes with significant economic potential (e.g. piping in industrial construction) may be justified if the synthesis of existing technologies support a high probability of successful development.

(7) Although processes involving the processing and assembly of solid objects are poorly suited to "closed loop" robotization, certain tasks within such processes may be candidates for automation with human support. For instance, although plumbing piping is a poor candidate for robotization, automation of the connection of piping using automated techniques (i.e. automated sleeving) and worker operated devices are good candidates for new technology application.

(8) Production of certain processes can be enhanced by using semi- or partial automation to reduce the skill level required of the human worker or operator.

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