ROBOTICS IN THE SWEDISH CONSTRUCTION INDUSTRY

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ABSTRACT

This article describes two R&D projects which are now in progress to develop robots for the Swedish construction industry. The projects are being carried out by two co-operating groups, one in the Stockholm area and one in the Gothenburg area. In addition to these projects, a long-term research project is being carried out jointly by the Royal Institute of Technology in Stockholm and Chalmers University of Technology in Gothenburg.

Today there are a number of robots - broadly defined - which are used for tunnel drilling, piling, demolishing concrete, load carrying, concrete grinding and floor cleaning. The Swedish construction industry utilizes such robots which have been developed both domestically and abroad. These robots are not described in this article.

Robots are also used in the manufacture of building components. For example, there are robots designed for painting bathtubs. Further, the manufacturing of small houses has been increasingly rationalized through the utilization of CAD/CAM techniques*. These robots are not described in this article, either.

PROGRAMMING AND NAVIGATION OF CONSTRUCTION ROBOTS

A major research project is being implemented in the Gothenburg area by a group of ten Swedish contractors called FoU Väst (R&D West) within the Swedish Construction Federation in Gothenburg. The project is being led by Platzer Bygg AB, and some of the research work is being carried out at Chalmers University of Technology, Gothenburg. The project is financed by the Development Fund of the Swedish Construction Industry (SBUF) and the Swedish Work Environment Fund (AMFO). A report was published at the end of 1988(1).

During the past year FoU Väst has been working on the development of a laboratory prototype. A prototype suited to field conditions will be produced later. The work has been

* Specifically designed by Nordisk Kartro AB, Farsta, Sweden.

concentrated on the robot's carriage, control system, navigation, software and path planning. The carriage of the prototype is equipped with two steerable drive-wheels and two supporting wheels. This permits all kinds of movement patterns. The carriage is fitted with batteries to power the electrical motors needed for the wheels and for the computer and control terminal.

The robot's control system is designed as a hand-operated unit connected to the carriage by a cable. In addition, there is an industrial terminal on the carriage. Both manual and automatic operation are thus possible. The control computer is a multi-processor system with large processor capacity. The robot can navigate in a number of different ways. One is through the measurement of distances travelled and control angles of the drive-wheels, after which the computer can determine position and direction. Another way is navigation by following cables in the surface of the floor. In a similar way it is possible to navigate with the help of the reinforcing iron bars laid in the floor. One possibility not yet evaluated is navigation with the help of laser equipment.

A computer on the robot carriage and a separate PC are used for processing data. This data deals with such things as the layout of the work area, the robot's speed and path, obstacles in the path of the robot, points for front and back wheels and continuous information about the position of the robot. With the help of the information about the layout of the work area, the robot's computer plots a suitable path for the machine. When plotting the path account can be taken of the need to cover the entire work-area without colliding with obstacles, to travel the shortest routes, to minimise overlapping sections and to achieve fast, simple path planning. The safety aspects have been taken into account by means of both sensors and a collision bar.

The work done on the prototype for laboratory use has provided valuable information about how the prototype for field conditions should be developed.

FUNCTION AND REQUIREMENT SPECIFICATIONS FOR CONSTRUCTION ROBOTS

A robot research project is also being run at the Department of Building Economics and Organization at the Royal Institute of Technology, Stockholm, in co-operation with primarily the Belab company of Stockholm. The project is financed by the Swedish Council for Building Research (BFR). A first report has just been published(2).

Until now the work in this project has been concentrated on the function and requirement specifications for the system construction of a multi-functional robot which should be capable of being used for plastering, grinding and painting of internal walls and ceilings. In the next phase the design of the robot's mobile unit and arm will be dealt with as well as the tools at the extremity of the arm.

The work on the function and requirement specifications for a multi-functional robot for internal work has led to a number of proposals. With regard to the mobile unit, one requirement which has arisen is that it must be able to move past such obstacles as thresholds and waste timber, perhaps also move up a staircase. This would indicate a load-carrier on caterpillar tracks. Many such units are available, including Swedish ones. A number of such mobile units are in fact merely hydraulically-powered load-carriers, but they can be equipped with automated controls.

The design of the robot arm is influenced by the fact that the robot should be static when the actual work is being done, so that the number of sources of error is minimised when processing walls and ceilings. The robot arm should therefore have extensive reach and could be an ordinary hydraulic arm. The hydraulic system is powered by an electric pump. However, such arms are not sufficiently sophisticated for the tasks to be performed, and their ability to move must be supplemented with further degrees of freedom. Joints affixed to plates should therefore be located as far out on the arm as possible. The intended tools should possibly work within a frame at the end of the arm. This frame is correctly located in relation to the work-surface with the help of a system of sensors.

Navigation can be handled in two stages. In the first, walls, apertures and the like are measured and the robot changes position in relation to these. In the second stage, the robot is placed in the correct position in relation to the work-surface. The robot navigates by means of sensors which interact with the control system. After completing work on a surface the robot moves itself into position for the next task.

For grinding and filling surface control is of great significance. For this purpose, for instance, a camera with a number of light-planes can be used, by which means depressions and bulges in the surface are revealed. Only grinding a surface or only filling presents no major complications. On the other hand, a suitable balance between grinding and filling is difficult to achieve, since regard must be taken of the materials and time used. Algorithms need to be developed for the measurement and classification of surface defects. Similar algorithms are also required for measuring large-scale deformations and for the measurement of such factors as doors, windows, electrical cabinets and the like.

For robots to be of practical use in construction work it is necessary to develop materials handling and processing tools. For grinding, a suitable concrete grinding machine is needed, which is connected to a vacuum cleaner. The filling can be done either with ready-mix material or with dry powder which is mixed with water in a combined mixer and pump. The supply of material can suitably be achieved by means of an automatic pneumatic system. During the actual filling work the filler needs to be both sprayed on to the work-surface and to be levelled. These tasks should preferably be performed at the same time. Painting is probably best done using a pressure roller connected to a paint-pump. The paint is applied to the surface and rolled out in a single process. It is important to avoid breaks in operation. Since the supply of filler is achieved via a hose it may be advisable to use cable for the supply of electric power to the robot. A communication cable for the control system can also be included in the same set of hoses.

A LONG-RANGE RESEARCH PROGRAM

The following three areas for research have been identified:

* Robotic systems
* Robotized construction process
* Socio-economic consequences

Robotic systems

In order to develop robots for construction work a large number of hardware problems have to be solved. These cover mobility, sensors, robot arms, gripping tools, heavy lifts, navigation and control. As for the software, the technology in the fields of photogrammetry, geodesy, laser and radio are of great interest. Increased understanding of the transmission of data and database support for the control of the robot are necessary. How might a product model in a CAD system be utilized for navigation information?

Robotized construction process

Research is needed to identify the need to adapt materials, working methods and construction methods to automated production. Robotization can also change design, other planning and construction site organization. What is important is to maintain or to raise the quality of the final product. Studies of the construction process and its various parts by means of simulation would appear to be suitable.

Socio-economic consequences

The successful use of robots presupposes that different groups of staff, including technical staff and construction workers as well as managers, should be given proper information and training. The fear of jobs being lost because of robots must be taken into account. The introduction of new technology has been the subject of research over a long period of time and attracts particularly strong interest in the case of robotization. In Sweden we have a long tradition of co-operation between employers and employees in the introduction of new technology. Employees have often been the ones who have pressed for change. It is possible that recruitment to the industry in the future will come from new groups. Robotization may perhaps lead to the appearance of a new category of construction workers. Research is also needed into the new work environment.

Not least important is an evaluation of robotization in respect of quality and economy. In the long run the robot must be able to offer unchanged or improved quality, increased productivity and good profitability.

Today the Swedish construction industry is well equipped to develop robot technology and to benefit from such development. Good conditions for this exist in the generally high technical standard, the advanced robot technology in manufacturing industry, the success achieved in information technology and the positive attitude to new technology within the Swedish trade union movement. What is needed is continuing forceful investment in R&D in accordance with a construction robot program based on national co-operation between the industry and the universities, as well as developed international co-operation.

References

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