Professor P.J. DRAZAN

Department of Mechanical and
Manufacturing Systems Engineering
University of Wales, Institute
of Science and Technology

Application of Robots in Construction Industry: Navigation of a Mobile Robot Robotic Welding of Steel Bridge Girders

Summary

Some views on the feasibility of the application of robots in the construction industry are introduced in the initial section of the paper and three approaches to robotic automation are listed.

The paper compares briefly the robotic activities in the building industry as carried out in various countries and mentions the UK and the recent initiative instigated by the Department of Trade and Industry.

In the later part of the paper the author introduces the Automation and Robotics Centre under which auspices the robotic work is carried out at the University of Wales Institute of Science and Technology. He then describes two projects which are relevant to the construction industry. One is the development of a mobile robot and its navigational means and the other deals with robot welding operations carried out on girders used for steel bridge construction.

1. Introduction

With the growing capabilities of computers and sensors it has been possible more recently to comtemplate the application of robots to more difficult working environments. Researchers have started developing concepts of 'Advanced Robots' which would be able to operate in a more autonomous fashion.

So far, the main field of robot application has been in factories, an orderly and predictable working environment. This environment has utilised the original primary asset of the industrial manipulators which is their manipulative capability-dexterity and their teachability. Some of the manipulators have been equipped more recently with sensors in order to provide them with a degree of adaptability.

In less predictable working environments the use of sensors becomes that much more important. The sensory information has to be processed by powerful software strategies, usually embraced under the term Artificial Intelligence. The enhancement of the sensory information by software to form an intelligent sensor will be of paramount importance in future robot systems.

2. Robots in Construction Industry

In certain areas, particularly hostile environments such as nuclear, subsea and also, one could argue, the construction industry, man cannot manage without the use of advanced robot systems or at least without automation which uses some advanced sensory means.

In the construction industry one can divide the potential application areas into the following groups:

1. Automation of existing equipment, eg tunnelling machinery equipped with laser beam inertial navigation.

2. Automation of existing processes dealing with volume manufacture of various building components, modules, sections, etc.

3. Use of robots for existing manual processes, eg bricklaying, concrete distribution and tasks of a similar nature, usually carried out on site and therefore subject to various adverse conditions.

3. World Scene

Already in 1981 the Ministry of Construction in Japan carried out investigation concerning the long term prospect of robot applications in the construction industry . Currently MITI is funding through the Advanced Robot Technology Research Institution (ARTRA) a national large scale research and development project for Advanced Robots. Three main application areas are being addressed: nuclear, subsea and firefighting and rescue.

In the construction field, Japan argues the need for the robotisation on the basis of bad safety record, low productivity, variable quality and the growing shortage of unskilled labour. It lists 14 areas of application as an objective for robotisation [1]. The Ministry has launched a $2 million research programme concerned with the use of robots in design, construction and maintenance operations. A number of Japanese firms have started applying the robot technology to tunnelling, concrete distribution, the placement of rebars, tiling, inspection, etc [2].

The American scene in the robot application to construction is different. Whilst in Japan there is a strong central governmental policy to provide impetus to robot research and application in construction and to co-ordinate the effort, in the United States the effort seems to be driven largely by the individual applications which require robotic solution [3]. Considerable activity exists at the Robotics Institute of the Carnegie-Mellon University which is engaged in projects such as the Remote Reconnaissance Vehicle designed to investigate the Two Mile Island contamination, the design of a pipeline robot digger, etc.

In Britain a small study sponsored by the Science and Engineering Research Council had been carried out last year by the University of Wales to investigate the use of robots in construction [4]. The report shows that the British construction industry has been slow in investigating the use of robots in its working environment. Admittedly, the emphasis on the short term return, hamper any more ambitious and conceptual approaches. However, there have been a few examples of good robotic projects carried out by several companies and related to the construction field. For example, the Central Electricity Generating Board investigated a robot capable of climbing a steel structure and a self-propelled robot mole inspecting underground pipes. A company in Derby is using V-laser equipment on a dozer to level ground surfaces. The Coal Board has been engaged successfully in a number of advanced robotic projects related to manless mining.

The Department of Trade and Industry in the UK launched a new initiative for Advanced Robotics (AR) during July 1985. The initiative aims at establishing a firm foundation for AR technologies and the longer-term manufacture of AR products in the UK by achieving good co-ordination at a national and international level for an effective research and development programme. The aim is to co-ordinate research in related AR fields primarily within the UK and with Europe and to provide assistance to strengthen the UK activity with a view to future AR market shares. Inaugural meetings organised by the DTI's AR Co-ordinator during the course of 1985/86 have brought together industrial, academic and research establishment interests in the UK to explore in a collaborative manner the following applications area:

1. Construction and Civil Engineering
2. Underwater
3. Firefighting and Emergency Rescue
4. Tunnelling
5. Nuclear Engineering.

The Department is currently sponsoring Feasibility Studies into the possible application of advanced robots to all of the above fields. The AR study for the civil engineering and construction application is being undertaken by the Construction Industry Research and Information Association (CIRIA) and will be addressing a wide range of potential applications for AR in hazardous and difficult construction environments.

In total over 80 UK companies and more than 30 universities and research establishments are provisionally involved in the collaborative activity that the DTI has initiated.

4. Research at UWIST Automation and Robotics Centre

The Automation and Robotics Centre at the Institute of Science and Technology of the University of Wales in Cardiff has been involved in the robot research programme for a number of years. It has been sponsored by the Science and Engineering Research Council, to carry out research in Automatic Assembly. Other research projects concerning the robot design and control and robot languages, visual inspection, aspects of FMS, etc, have been tackled by the researchers working in the Centre. The Masters course in Systems Engineering which has 52 students this year also contributes to the research in robotics in the form of four month projects carried out in liaison with industry. Since the last year the Centre established an Industrial Unit which caters for shorter term R&D work to assist companies. The unit is supported for two years by a special Urban Aid Grant received from the Welsh Office.

5. Related Projects

Although most robotic projects undertaken in the Centre so far have been concerned with the manufacturing industry there are projects which are relevant to the construction industry. Such is, for example, a mobile robot project which investigates suitable navigation means for freely roving robots.

Navigation of a Mobile Robot

The control system of the mobile robot contains a map of its working environment and the pre-programmed path for it to follow. The navigation system is based on a rotating ultrasonic sensor which scans the surroundings. The robot is guided primarily by odometry. The accumulated error is then corrected by the use of ultrasonics [5].

The aim of the project is to develop simple means of navigation. Initially, attempts had been made to improve the resolution of the sensor by narrowing its beam to 9°. Thus the sensor can recognise the gaps of 39 mm at 5 m distance. It was found that the sensor can only determine accurately surfaces perpendicular to its beam. The other surfaces cannot be identified correctly due to the multiple reflections of the beam. This is illustrated in Fig 1 where a test environment consisting of three mutually rectangular surfaces is scanned through 180°. The straight lines indicate the map stored in the memory. The crosses indicate the sensor readings obtained from the scan. It can be seen from the figure that the only readings which can be used are those which were taken perpendicularly to the walls. The sections of the map which can be read correctly can be predicted and are indicated in the figure by broken lines. Those are the sections which are used for navigation. Therefore, the strategy used is as follows: as the mobile moves along the path the map is reduced to a set of surface sections perpendicular to the position of the scanning beam. These sections are then compared with the appropriate readings obtained from each scan.

The work shows how relatively simple sensors can be enhanced by intelligent software to deliver more comprehensive information. Although this mobile is not able to navigate in an unpredictable terrain it can cope with construction sites containing walls, various openings, etc.

Robotic Welding of Steel Girders

Another project undertaken in the Centre is the use of a robot for the welding of studs to the girders used on steel bridges. Girders are manufactured by profile cutting of plate steel to the desired contours and then by welding the cut sections together to form the I-beam. To provide adequate anchoring of concrete decking to the steel girders a regular array of mushroom headed steel studs is welded to the uppermost flange of the girder (Fig 2). Eventually protective paint finishes are applied to the girders.

Recent years have seen the introduction of advanced numerically controlled equipment to cut the required profiles of the web section of the girder so as to automatically weld stiffness to the girder. The stud welding process has been carried out so far manually. The robotic welding described below is the subject of the project.

When the stud welding operation is performed manually the stud positions must be marked before the welding operation can start. The marking is time consuming and it is estimated that it takes one third of the time attributed to the whole operation. When the process is automated it does not require pre-marking. The welding takes a long time as there are typically 400 studs welded to one girder. Throughout the operation the welder has to carry the gun which is tiring and also somewhat hazardous.

There is no doubt that the automation of the stud welding offers considerable advantages. The whole operation would be pre-programmed, requiring no attention from the operator over an extensive period of time, say two hours. Although direct time saving is not expected from the automated welding operation it is going to produce a more reliable and consistent result.

The main difference between a typical robot application in a factory and the robot application in the construction industry is that the construction components and structures are normally much bigger than the products manufactured in factories. Consequently the robot, when applied in the construction environment, has to cover a considerably bigger working area. Such is the case of the stud welding application where the length of the girder would normally reach 25 metres. The problem faced is to find suitable means to transport the robot along the girder.

A track carrying a robot can be placed along the girder either on the floor, or, to save space, on a side wall, or even suspended from a gantry placed above the girder. The provision of a tracked robot has an advantage of its potential use for other operations such as metal or paint spraying. The disadvantage of this solution is that the girder has to be aligned with the track. A coarse alignment may be sufficient as simple sensing means could be used to align the robot program instead of aligning the heavy girders.

However, an alternative solution offers more potential for the future use of advanced robots in the bridge construction. The tracking means required to guide the robot along the girder can be obtained by direct use of the girder. Because the girder is manufactured to a reasonable degree of precision a carriage carrying the robot can be run on the girder thus aligning the robot automatically (Fig 3). This approach allows the robot to be used on the construction site. The robot application will be extended to the welding of the girder splices which is a very time consuming and difficult operation. The robot is hoisted on the girder and then left alone to move by its own means to perform the specified task. There are three main aspects of this operation:

1. A suitable self-propelled mobile base carriage has to be provided for the robot. The carriage is equipped with locking mechanisms to secure the robot automatically on the girder.

2. A correct choice of the robot configuration has to be made (see Fig 3) to enable the robot to reach all the necessary locations on the girder.

3. Suitable sensing means have to be employed to position the robot correctly on the girder. Although the tracking provides the coarse position this information has to be supplemented by sensing means identifying the exact location of the splice.

6. Conclusions

The potential of the use of robots in construction is considerable and offers to the researchers and engineers an interesting challenge.

Undoubtedly the main thrust of research will go into designing intelligent software which will be capable of making decisions when faced with unpredictable situations. But it is also certain that considerable effort will have been spent on designing mobile systems suitable for various working environments. Providing that the sensory systems will be engineered into robust and economic packages, the reward of the use of the advanced robots in construction can be considerable.

7. References

[1] T Furukawa, et al, "Automation and Robotisation in Construction Work", Robot, No 38.

[2] Anon, "Robots Contribute to Construction Productivity", Kajima Perspectives, Vol 5, No 2, 1985.

[3] R Egginton, "Visit Report for the Robotics in Construction", DTI Report MEE 78/09, July 1985.

[4] K I Majid, "Robots in Construction Industry", University College, Cardiff report, December 1985.

[5] B Keepence, "Absolute Position Determination for a Mobile Robot", ARC Technical Note, No 12, UWIST, Cardiff, April 1986.

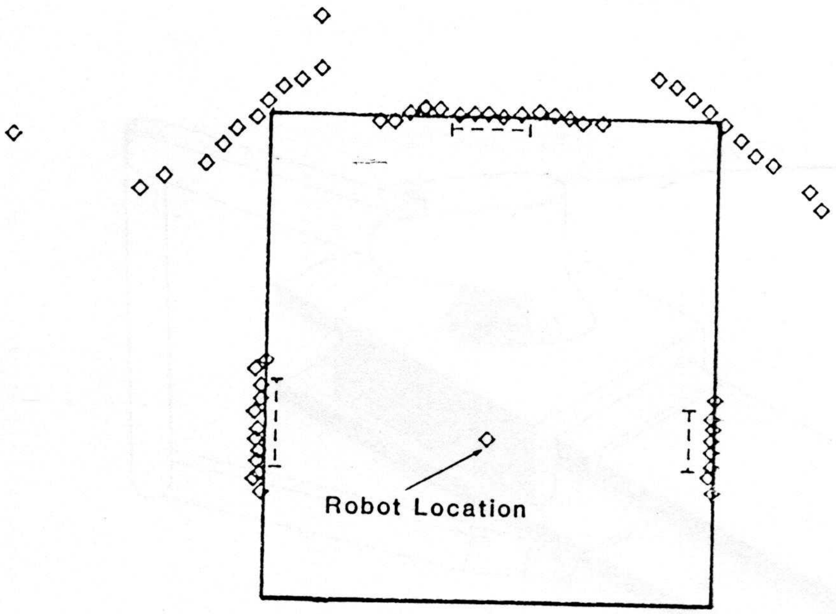

Fig. 1

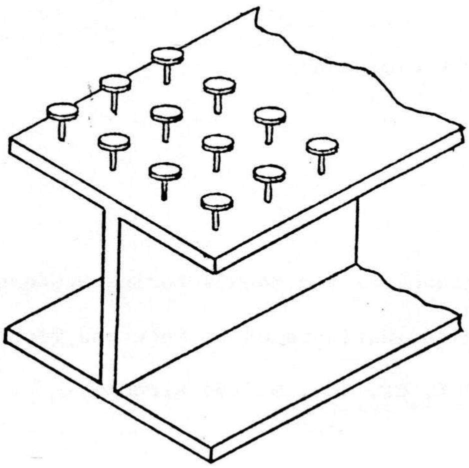

Fig 2

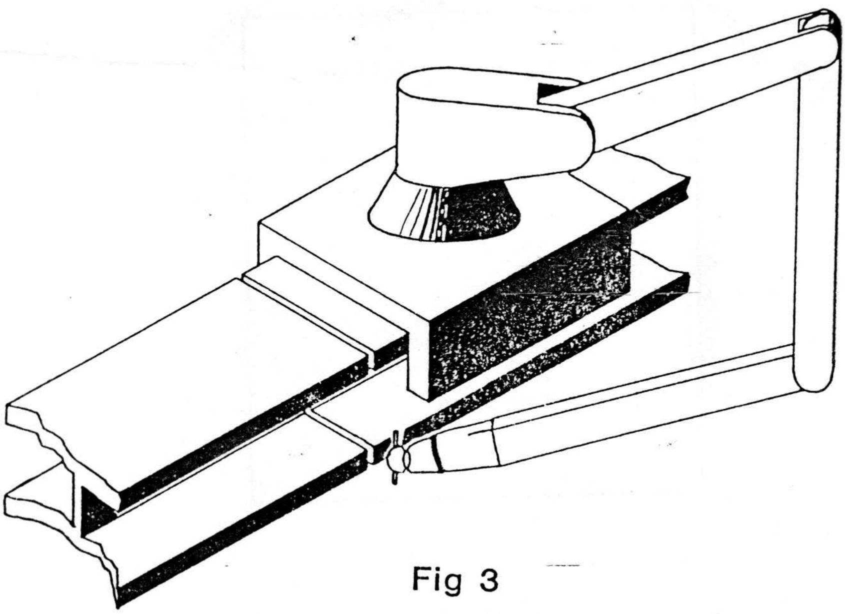

Fig 3

Professor P J Drazan

Department of Mechanical and Manufacturing Systems Engineering

University of Wales Institute of Science and Technology

PO Box 25, Cardiff, CF1 3XE, United Kingdom

0222 42588