INTELLIGENT ROBOTS FOR CONSTRUCTION

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SUMMARY

Of all industrial groups, construction represents one of the most challenging sectors for the implementation of Robotics. There is a subset of construction related activities - notably those involving work in hazardous environments such as tunnelling, undersea tasks, and nuclear installations - where there are very strong incentives to develop robotics. However the bulk of contruction activities, which constitute the main subject of this paper, are inherently difficult to mechanize let alone use robots economically. It is argued in the paper that the use of non-intelligent industrial robots in construction is likely to be limited to a small minority of tasks associated with the finishings and service installations. Thus to make progress, intelligent robots will be required to operate in the uncontrolled environment of the construction site. The paper will identify the approach to robotics development most likely to prove helpful to the needs of construction.

KEYWORDS

Intelligence, Robotics, Vision, Behaviour

1. BACKGROUND TO ROBOTICS RESEARCH

1.1. Early work in intelligent robotics

The history of research into intelligent robotics can be traced back to the late fifties with the work of Marvin Minsky, who with others attempted to build a robot cabable of playing table tennis but were forced to abandon it because of limitations in the electro-mechanical parts used. Later they produced a 'ball catching' machine which also proved to be unsatisfactory because of the slow speed of the camera and the mechanical arm used (Malcolm *et al*, 1989).

At this time robotics research was closely related to that of Artificial Intelligence (A.I.). The problems encountered by the early pioneers of intelligent robotics generally stemmed from the inability of the electro-mechanical and sensing devices, available then, to match the requirements for an intelligent robot. This lead to a schism in robotics research.

1.2. The schism in robotics research

The first approach was to concentrate on the electro-mechanical aspects of the task of building robots. This could take the form of developing non-intelligent industrial robots to service a production line or else it would involve work on intelligent robotics with the implied assumption that the 'artificially intelligent' bit will be perfected by others at some unspecified date in the future.

The second approach involves concentration on problems associated with 'artificial intelligence'. This, being divorsed from the reality of the mechanical, electrical, and sensing devices, became a purely symbolic approach. Since the level of sophistication of the models developed was, in any event, initially beyond the capabilities of the rudimentary elecro-mechanical devices available, the only form of real verification they were ever likely to be subjected to involved simulation.

Such simulations are unlikely to identify the kind of problems faced by a robot in reality given the impact of marginal errors in sensing and implementing a plan. For example, in the case of a robot undertaking an assemply task, while a simulation might operate on the assumption that the information from sensing devices and the implementation from the robot arm were precise and accurate, in practice, this is unlikely to be the case. Thus inaccurate information from the sensor or imprecise movements from the robot arm could render the most sophisticated 'intelligence system' useless.

Thus a clear divergence has evolved between robotics and artificial intelligence research. It can, however, be argued that even if if it were possible to produce workable robots from the somewhat utiopian theoretical models developed, it is fundamentally unsound to attempt to divorce the sensing and planning from the implementation stage. Thus a move towards the synthesis of the two approaches has developed notably at M.I.T. and the University of Edinburgh with emphasis on the *building* of intelligent robots.

1.3. The emerging paradigm in robotics research

It has been argued that the recent developments in robotics research at Rochester, Edinburgh, Massachusetts Institute of Technology, etc, can be said to present an emerging paradigm in robotics research (Malcolm *et al*, 1989). This can be seen as a type of dialectical synthesis of the 'mechanical engineering' and 'cognative science' approaches outlined above, dealing with the fundamental flaws inherent in both approaches while retaining the strength of each.

The distinctive features of this emerging paradigm when compared with classical robot architecture, as outlined by Malcolm *et al* (1989), include, amongst others; the fusion of the sensing and the actuating mechanisms, an active use of the world, and a general distaste for symboloic reasoning.

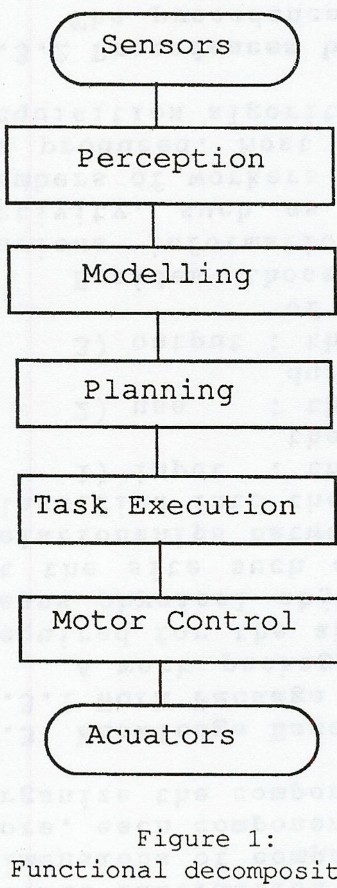

Figure 1:
Functional decomposition.
Source: Malcolm *et al* (1989)
after Brooks(1986)

Thus rather than the arrangement included in figure 1 opposite, with essentially a **functional** discomposition of the required operations the sensors and the actuators work together to avoid objects, wander around, explore, to build maps, identify objects, and to plan changes - a form of **behavioural** decomposition.

For example, in the case of a robot stacking blocks, the 'classic' approach would be to employ the sensors to identify a precise location and use a planning technique to place the block in that exact location. It is highly likely that either the sensors or the planning process or the actuators will be imprecise/inaccurate and the block placed in a unstable position. The adaptive approach would instead employ the actuator to 'feel' if the block was correctly placed and to nudge it into place if not. The position would be judged in **relative** rather than **absolute** terms in the same way that a human would stack blocks.

This approach involves essentially a *bottom-up* adaptive approach to planning rather than the *top-down* utopian approach of the classic school. It endeavours to take advantage of the environment and use it positively rather than as something to be overcome by ever more sophisticated sensing devices, more accurate actuators, and vastly more processing power.

2. THE CONSTRUCTION INDUSTRY

2.1. Overview of the problems of robotics in construction

Construction presents a major problem for the implementation of robotics in mainstream work. This stems from both technological and economic issues. There remain a number of specific tasks where safety considerations are likely to provide a powerful incentive to overcome the technical problems and also to over-ride the economic objections. The items coming into this category include many tasks related to tunnelling and to off-shore and undersea construction. In addition the kind of work associated with the decommissioning of nuclear power stations may also prove amenable for such mechanization.

While such tasks may provide the imputus for research and development work which might ultimately have spin-off benifits in more conventional tasks, this is beyond the scope of this paper.

Mainstream construction tasks do have a number of characteristics which make them difficult, or at least uneconomical, to use robotics in normal circumstances:

i) Construction activities generally suffer from the lack of a controlled environment - there are major variations in temperature and relative humidity not to mention the lack of a smooth and obstruction free floor - thus creating problems for which do not apply in the controlled environment of a factory or office.

ii) Construction has, in proportion, fewer repetitive tasks than manufacturing and also for that matter; commerce.

iii) The work tolerances which are traditionally used in construction tend to be much wider than those in use in other production industries - this is likely to present problems in the cases where automated tasks follows immediately behind a task carried out manually.

Clearly such problems will place a great strain on the sensing, planning, and implementation techniques required to be developed for robotics in construction. Specifically, it is likely to severely limit the application of such 'non-intelligent' industrial robots to a small subset of construction activities. Alternatively tasks may become more amenable to the use of robotics if they are shifted off-site to the factory - *e.g.* prefabrication or system building. This would also shift the S.I.C. classification of the work from 'construction' to 'manufacturing' (C.S.O., 1979) and thus go beyond the scope of this paper.

2.2. Tasks within building construction

The tasks associated with the construction of a building, while many and varied, can be grouped into the following broad categories:

Site clearance and external works
Substructure
Superstructure, cladding, and structural frame
Fittings and finishings
Service installations

Of the above groups, the first three all involve the specific problems outlined above in that they are carried out in an external (and hostile?) climate and environment. There is generally no smooth working surface, the site will probably be covered with physical obstructions, and space may be extremely confined. In the above situation it is hard to visualize a single application for an industrial robot which could lead to any operational or economic advantage. It remains possible to have a robot driven scraper to remove surface soil from a smooth and obstruction free site or, for that matter, to have other robot controlled plant. It would be, however, essential for the latter to be 'intelligent' and equipped with sophisticated sensors - preferably vision - for such to be of any practical use.

In the case of the finishing trades, it is easier to see applications for industrial robots for such tasks as floor screeding, plastering and painting. In such situations, only the door and window jambs are likely to create problems unless the workmanship and precision of the construction of the structural members - floors, walls, frame - and the partitions lead to difficulties in achieving the required cover. In the case of the installation of fittings and services, the degree of adaption required to 'persuade' such items to fit into where they are supposed to fit, again makes the use of industrial robots somewhat implausible in most circumstances.

It may be questioned as to whether the use of industrial robots for such a limited set of tasks is worth the disruption likely to be created in terms of quality control of prior tasks and the need to clear the floor of obstructions. While not specifically excluding the possibility of the use of robotics in construction, this suggests that any robots used will need to be 'smart' in order to cope with the hostile environment - this is quite dissimilar from the controlled conditions of a factory production line

2.3. Tasks within civil engineering construction

In the specific case of civil engineering construction, the same issues apply as for building construction. Thus it is likely to be possible to find a limited range of tasks suitable for industrial robots, but, in practice, it remains doubtful if this will be economically or operationally viable unless safety is the critical factor as in the case of off-shore or nuclear installations.

If anything the external environment is likely to be more hostile in the case of civil engineering than is generally the case in building. Thus, again, if robots are to be employed, they must be equipped to cope with this external environment.

3. CONCLUSIONS

The demands placed by construction on any attempt to implement the use of intelligent robotics: the need to provide a very sophisticated sensing system - preferably some form of machine vision - and the requirements of a massive range of planning techniques to deal with the number of situations likely to be encountered, etc. are likely to require massive processing power to be achieved with traditional robot architecture, if indeed such is feasible. The approach inherent with the emerging paradigm is more likely to produce results given the nature of the electro-mechanical technology available now and in the forseeable future.

It is probable that the initial advances may come in those tasks where safety issues are paramount, or in prefabrication tasks carried out off-site. Nevertheless it remains desirable to identify the potential for the use of intelligent robots in traditional on-site activities.

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