ROBOTICS RESEARCH IN THE UNITED KINGDOM

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Abstract

A review of current U.K. research on manipulative and mobile robot systems. The review will include those aspects of remote control which overlap robotics. Work in both academic and industrial laboratories will be covered.

Robotics research in the U.K. has for a long time been fragmented and poorly funded. Nevertheless, notable contributions have been made to robotics. The recent growth of industrial awareness of the potential of robot devices has been brought about by the efforts of the existing laboratories acting in conjunction with industry.

Overview

Despite neglect and persecution, robotics research in the U.K. has managed to survive and to show clear evidence of survival. Although the number actively involved in robotics research has remained at about the twenty mark or below for the last ten years, the U.K. effort has kept pace with worldwide developments and has frequently pioneered within this demanding subject.

Robotics is an ill-defined topic merging into artificial intelligence, production engineering, image processing, weapons systems, dynamic and kinematic control, prosthetics and even entertainment. To narrow the field we shall concentrate on those developments directly relevant to robot systems, excluding closely allied developments such as speech recognition.

It is difficult to identify a starting point for research. Clearly the mechanical devices developed by Thring and the cybernetic devices of Grey-Walter, Ross Ashby and Young were immediate precursors, whereas the early Freddy robots of Michie and his group at Edinburgh, backed up by dedicated mainframe computing power, were well into the mainstream. The research effort has been distributed and greatly dependent on individuals rather than teams, but has grown in a way which has led to a good coverage of the subject collectively; overlaps have been complementary rather than competive. It is possible to select subsets, say of industrial manipulation, or of mobile systems, which although large topics in themselves will demonstrate internal specialisation between institutions. This separation has been more due to the scarcity of resources than to intentional planning.

Recently the Science Research Council has realised that the U.K. has neglected the area and that there is a need to rectify matters. A sum of £2.5 million, over three years, has been earmarked for industrially relevant robotics research. Welcome though this move is the figure is very much below that available elsewhere. Industrial support has been a long time coming. Indeed it is a sad fact that U.K. industrial awareness of the potential of industrial robotics was largely due to the efforts of academics such as Heginbotham, Popplestone and Larcombe in the setting up of the British Robot Association and the subsequent vigorous publicity and information campaign mounted by that body. It might also be added that a single Fiat television commercial showing the robot production lines had as much galvanising effect as three years of private lobbying.

Edinburgh

Prof. Donald Michie's group at Edinburgh and the subsequent divisions and mergings have been associated with many well-known names in artificial intelligence and robotics - Popplestone, Barrow, Burstall, Ambler, to name only the longer serving of that group. Artificial Intelligence studies at Edinburgh may have grown out of Donald Michie's matchboxes but for a period of perhaps five years was centred on robot hand-eye systems. The main research tool was an unconventional manipulator, Freddy, which is a large fixed manipulator on a parallelogram frame with links about .5m long terminating in 'grippers' of about 2cm by 2cm area. Instead of moving this manipulator the entire operating environment was moved on a large X-Y table of the order of 2.5m by 2.5m. The TV cameras were usually fixed to the manipulator support frame. Considerable effort was expanded in designing the necessary interfaces between camera and computer. Such interfaces are now off the shelf components, but robot researchers have frequently to make excursions to develop instrumentation, which divert efforts for considerable periods.

In order to be able to interactively program this system in a congenial way, Popplestone developed a very flexible language, POP-2, which had available the list processing power required to support the Edinburgh A.I. philosophy yet was interactive without the need to count endless brackets. Using this system considerable advances were made in computer interpretation of images. When brought to its zenith the system was able to assemble a wooden toy car from a jumbled heap of components including non-relevant components. To conduct this assembly single-handed a simple manipulator operated clamp was used. In order to improve grasping and insertion operations, a limited degree of gripper force or tactile sensing was used.

In recent years the robot research has drifted apart from the A.I. research effort. It has been found by more than one group that the delicately structured linguistic processing that is used in A.I. is ill-suited to the demands of real-time robot control.

Current Edinburgh robotics research is concentrating on the development of languages for automatic assembly. These languages are thematically close to the APT language used for programming numerically controlled machine tools. The nub of such languages is their geometric data base which describes real world items in terms of a set of geometric primitives and their joins and intersections. Such a database is well suited for manipulator control using relatively simple feedback systems to allow for tolerance.

Nottingham

Prof. W. Heginbotham of the Department of Production Engineering and Production Management (now Director General of the Production Engineering Research Association) and Dr. A. Pugh of the Department of Electrical Engineering (now Professor of Electrical Engineering, University of Hull) were principals in the study of industrial manipulators. Prof. Heginbotham was probably one of the first academics in the U.K. to understand the potential of industrial manipulators and he has been very active in the promotion of their use. Much of the work was carried out under the aegis of the Wolfson Industrial Automation Group at Nottingham and was largely industrially sponsored.

The close involvement with production engineering showed the need for sophisticated simulation tools for evaluating the capabilities of existing industrial manipulators. Accordingly a CAD system was developed which allows the geometric and time constraints to be displayed. This system gives a graphic display output and allows rapid assessment of most common manipulators.

The group have been involved in research into assembly robotics and into the problem of developing ordered component presentation for automated assembly. Prof. Pugh conducted much of the U.K. research into the use of limited vision (essentially two level images produced by appropriate back lighting) in assembly work. The SIRCH robot showed that an industrially feasible system could be devised for discriminating between components and for orienting and positioning certain classes of component. In the development of industrially feasible systems a tight rein must be held on system cost and complexity.

Prof. Heginbotham is continuing and expanding the industrial robot development at PERA and Prof. Pugh is continuing research into assembly robotics at Hull. Dr. C. Page, formerly a research student under Pugh, is now conducting assembly robotics research at Lanchester Polytechnic, Coventry.

Surrey

Dr. P. Drazan has been experimenting with pneumatic manipulators under microcomputer control. The cost of industrial manipulators is largely due to the high cost of their predominantly hydraulic actuation. Both hydraulic and electrically actuated manipulators suffer from the high inertia of their actuators and the structure necessary to carry the actuator. Pneumatic actuation allows the construction of lightweight, low inertia, fast acting manipulators. The technical problem is the intrinsic compressability of air which if uncompensated leads to sloppiness and bounce. Drazan's solution lies in predictive control using a microcomputer, and the use of rapid acting brakes to cut out the oscillations.

Despite promising results there have been difficulties in exploiting this work.

University College London

E. Ihnatowicz and Dr. B. Davies have produced a series of very elegant electrohydraulic small scale manipulators. By avoiding standard components the mass of the manipulator may be greatly reduced. The U.C.L. manipulators merge actuator and structure and by always using opposed cylinders create a tightly controllable fast actuator. The use of pressure feedback directly from the actuator as well as position feedback gives a significant improvement in the flexibility of control. Operations of a contour-following nature may be performed without further external sensing.

Versions of the U.C.L. arm have been supplied to the National Engineering Laboratory and to the University of Warwick. Commercial exploitation is at present problematic.

Queen Mary College

Prof. M.W. Thring of the Department of Mechanical Engineering developed a number of early mechanical and essentially servo-controlled robotic devices. Many of these devices were concerned with flexible locomotion, such as stair climbing mechanisms. Prof. Thring has moved away from robotics per se and now concentrates on paraplegic aids and telechirics (remote manipulation).

Dr. A. Bond of the Department of Computer Science has used a number of small robotic devices in conjunction with artificial intelligence software systems. At least one mobile device has been built which is capable of a degree of autonomous navigation using optical, acoustic and mechanical sensors.

Warwick

Dr. M. Larcombe, M. May and latterly Dr. G.R. Martin have specialised in mobile robotics over the last ten years. The program was based on the geometric real world modelling systems used in CAD and combined the use of geometric maps with simple sensing systems to give an autonomous navigation ability. Subsequent development of sonar and tactile sensors greatly extended the flexibility of the mobile robots, and provided protection from impact. The use of multiple sensor systems including optical mark readers, magnetic detectors, tactile probes and line scan cameras has led to the development of integrated navigation systems which tolerate very high levels of noise without loss of position and orientation. Most of the experimental machines carried manipulators and to increase the flexibility of these tactile feedback was adopted from the outset, using a carbon fibre sensor developed at Warwick for this purpose. The sonar, which again had to be developed for use in air at Warwick, was chosen because its delivery of immediately useable information was at a rate which did not overtax the control computer.

The current machines are self-contained using small onboard micro-systems capable of handling all map data, navigational and control algorithms typically within 8K 16-bit words.

The methods used at Warwick have been successfully applied to the navigation and control of remote-controlled submersibles and to the navigation and control of marine oil drilling platforms.

The Warwick group are now involved in the development of Free Roving Automated Industrial Trucks (FRAIT) under Science Research Council support and in conjunction with Lansing Bagnell Ltd.

Dynamics and Kinematics

The dynamic control of manipulators leads to some appalling control problems. Manipulators are mechanical linkages and their kinematics alone lead to the production of difficult computational problems; the addition of dynamics produces a mathematical model of staggering complexity.

Dr. J. Duffy, formerly of Liverpool Polytechnic, has produced the most exhaustive kinematic analysis of manipulator mechanisms. This work is, however, only likely to be understood by two or three robot engineers in the U.K. where (unlike the Eastern bloc countries) this area has been severely neglected. Fortunately, Dr. J. Hewitt of the Department of Mechanical Engineering, University of Newcastle upon Tyne, has turned his attention to the simplification of the dynamic control problem. A new scheme proposed by him involves a method at once simple to implement and ingenious in concept. Essentially there are functions in the control equations which are laborious to compute, frequently due to the kinematics, but which can be directly measured by instrumentation. In addition it is possible to make quite ruthless approximations and to compensate for the approximation by using compensatory feedback.

Other Workers

The above headings are by no means exhaustive and are clearly academically based. In the last few years a number of other individual academics have taken interest in robotics, and there are others who have been working in closely allied fields such as pattern recognition. In addition, a number of industrial projects have involved substantial innovation such as the BOC-Hall Automated Welding development or GEC-Marconi's Landfall automatic vehicle navigation system. The National Engineering Laboratory has been conducting research into robot welding for several years in conjunction with the Welding Institute.

A Background

A research area, apparently quite active, of centres which have in many cases international reputations. Yet until quite recently only a few enjoyed SRC or other support. Such SRC support that was given was thinly spread and that mostly between Edinburgh, Warwick and Q.M.C. London. Industrial support was mostly for the Nottingham team's application of existing equipment, little if any for forward research. This state of affairs came about because of two disastrous factors: the low level of technical awareness in U.K. manufacturing industry and the Lighthill report.

There was almost no need-pull from British industry; robotics was thought to be the delusion of a few remote academics. The few industrial voices such as I.C.I. and BOC who publicly supported the need for more expertise in robotics were not enough to break through the general level of ignorance.

On top of this wall of ignorance and inertia settled the Lighthill report. Commissioned by the SRC, Sir James Lighthill, F.R.S., an eminent applied mathematician, investigated the field of artificial intelligence including robotics with the intention to guide the SRC in its spending in the area. In a survey in which it was clear that Sir James had either avoided or been directed away from those actually involved with practical robotics, as against robots used as tools within A.I. studies, he reached the conclusion that robotics was an unfruitful avenue. It was clear from the report and from Sir James' presentation that he had seized upon the idea that robotics was the quest for the general purpose sentient machine. This at a time when most workers were more than content if a manipulator could pick up a stud without dropping it two times running! The author was indeed fortunate to get away under the wire, the Warwick work being classified as advanced automation (good in Sir James' view) as against robotics (bad in Sir James' view). Wryly the report was published within days of our first grant announcement, leading to the technical press wondering whether SRC's left hand knew what its right hand was doing.

From 1972 onwards conferences and symposia on robotics were held quite frequently. Time and again there were calls for greater investment in U.K. research and development. Both the SRC and the U.K. Department of Industry vacillated, appointing unending review bodies and commissioning surveys and generally avoiding the issue.

In 1976 the author in conjunction with Popplestone at Edinburgh and Heginbotham at Nottingham held a meeting at Warwick to which were invited all known research workers in all known interested industrial concerns. The intention was to set up a British Robot Association on similar lines to the Japanese Industrial Association (JIRA) and the Robot Association of America (RAA) to serve as both a pressure group and as an information clearing house. To the relief of the academics there was considerable backing from industry and the new association was set up with a predominantly industrial committee. The Association almost immediately attracted industrial support and eventually a grant in aid from the Department of Industry. By mounting seminars and exhibitions the Association both promoted industrial robotics and demonstrated a rapid growth in industrial awareness.

In parallel with this development the author was able to persuade the BBC to present a number of documentary programmes on the theme of the new technology and robotics in particular. One of these, the BBC Horizon programme 'Now the Chips are Down' was instrumental in putting the words 'chips', 'new technology' and 'robotics' into the political vocabulary. One intriguing side effect of this programme was to stimulate the then Prime Minister, James Callaghan, to enquire of the Department of Industry of their plans within this area only to discover that there was no section of the Department with specific responsibilities for either integrated circuit development or industrial robotics. Such is the rapidity of response that we still have no large scale VLSI production and only one UK robot manufacturer (GEC-Hall Automation) two years later.

The current governmental view, reached after yet another expensive and long unpublished survey (the Ingersoll report), is that robotics is a good thing but that market forces should govern development and that no direct government support is necessary other than that from SRC under a shuffling of priorities. It might be mentioned that the £2.5m sum mentioned constitutes about 0.6% of SRC funding. This new SRC 'initiative' is however restricted to projects which have an industrial co-operating partner. Since industrial partners are generally recent arrivals on the robotics scene the net result may be a further deadening of forward research and should be viewed with caution.

Taken all in all the support and exploitation of U.K. robotics research (at least in the U.K.) has not presented a picture to be proud of. The effort so far has shown considerable productivity, unfortunately too much of that has been in the export of ideas and of research workers. Indeed it was only the recent provision of near realistic support funding that restrained the author from adding to that export figure in person.

Discussion

Professor Randell thought that there might have been a misunderstanding of the Lighthill report; different people seemed to have gathered different impressions. **Dr. Larcombe** certainly had the impression that the report was untimely. **Professor Randell** went on to say that he believed that there was a division between Artificial Intelligence (AI) and Industrial Automation (IA), but also that the work in the middle ground tended to move from AI to IA and thus the criticisms tend to move that way also.

Professor Michaelson considered that one effect of the Lighthill report had been to generate "pseudo-science", attempting to look like Physics. If proposals were not stated in a pseudo-rigorous form then funds might not be forthcoming. The opinion had been expressed that the Lighthill report was used as a "political hatchet job".