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ROBOTICS AND INTELLIGENT MACHINES IN AUSTRALIA - A STATE OF THE ART REPORT

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ABSTRACT

In this paper the current state-of-the-art in advanced automation and robotics in Australia is reviewed. The paper briefly documents the history of robotics research in Australia and identifies the stage in the technology development cycle that has been attained. It is thought that the end of the start phase has been reached. The paper also reviews a variety of specific research projects and prototype systems under development at various research institutes and Universities across the country. The paper concludes that a lively and broadly based research effort in the country is underway albeit on quite a small scale.

1. INTRODUCTION

At the present time and throughout the world, many groups of researchers within Universities, research institutes and companies are actively involved in trying to develop robotic and quasi-robotic systems to improve and change the nature of the construction and building process. The form and nature of the research and development work being undertaken by these groups is many and varied and comprises both fundamental research into the elemental technologies that are necessary for robotic machines and also work related to the field applications of the composite technologies. The range of work defies simple classification.

Consistent with this world wide effort, research teams in Australia are likewise active in this field of research. The research effort in Australia is quite diverse even though the small amount of research funds available restricts the kind and scale of project that can be undertaken. The scope of activity underway covers both the construction of robotic machinery and the devising of computer controlled (robotically directed) construction process and systems

The aim of this paper is to review some of the work currently being undertaken in Australia and to present a broad picture of the state of construction research in the country at large. The intention here is to inform the international research community of this activity and to create a wider awareness of the kind of work that is being carried out in countries apart from the major industrialised ones.

This paper updates and complements an earlier paper presented to the 8th ISARC conference in Stuttgart in 1991 (Ref 1)

2. TERMINOLOGY

In this paper the terms "construction robot", "telerobotic machine" and "smart machine" will be used in a specific fashion.

- The term "construction robot" will be used to refer to a general purpose machine whose behaviour can be significantly altered through software. The machine is controlled by computer with minimal or no human intervention.
- The term "telerobotic machine" is substantially the same as the full robotic machine except that in the case of the telerobotic system the machine is under the instruction of a human working from a remote control panel.
- The term "intelligent or smart machine" will be employed to refer to substantially single purpose machines whose behaviour is under computer control or which has inbuilt sensing and/or cognitive capacities.
- An autonomous machine is a smart machine which not only is under computer control but has its own internal goal setting and goal seeking processes built into it.

3. AN OVERVIEW OF CONSTRUCTION ROBOTICS RESEARCH IN AUSTRALIA

3.1 The General Stage of Development

It is probably quite fair to say that construction robotics as a field of endeavour in Australia is in its infancy and is predominantly going through an exploratory and early learning phase. This phase is hopefully a precursor to the development of economically viable commercial systems. The work being done appears to be at the very early stage of an archetypal technology development cycle and is at the earliest phase where various ideas are being explored and alternatives investigated. Little in the way of commercial product though has been generated. This is typical of a major technology in its nascent or embryonic period. The construction robotics industry is possibly similar to other new industries, such as the laser industry, where commercial applications lagged considerably behind the key technology development.

It is clear though that despite its nascent state that Australia has taken the first step in the process of technology exploitation and has begun to develop the rudiments of a identifiable construction robotics industry whose identity is distinct and separate from that of the established manufacturing robotics industry. This is considered a major step forward since only when the field has been established can work on solving the distinctive problems of the civil and building construction industries be addressed and hopefully progressively solved.

The current major centres for construction robotics in Australia are the University of N.S.W. (UNSW) in Sydney and the Commonwealth Scientific and Research Organisation (CSIRO) in Melbourne. It is noted that construction robotics work in Australia is being spearheaded by the University and research sector in a form of "technology push" form of development rather than the commercial or contractor based "demand pull" form of development which seems to be the current situation in Japan.

3.2 Historical Development The origins of the Australian Construction Robotics Industry can be defined quite precisely.

i. In 1983 the Author purchased a small stepper motor controlled teaching robot and began to use it for study purposes at UNSW. A number of demonstration programmes were developed and problems of vision control and others begun to be studied. Support for the concept and work was not high and the project was shelved - it being considered that this technology was too "high-tech" for the

industry. It was thought that the work was in advance of its times and a conscious decision was made to delay further work on the technology for another 10 years or so until a more favourable environment would be available.

ii. In mid 1988 Donald Gibson and Ronald Sharpe of the Division of Building, Construction and Engineering of the CSIRO perceived the opportunities implicit in robotics in construction and held a public seminar on the possibilities of an Australian construction robotics industry (Ref 2). To this meeting members of the public, academics and researchers, union leaders and business organisations were invited. Professor Hasegawa of Japan was an invited speaker.

Whilst some researcher interest was generated from the meeting little public or commercial interest from the construction industry followed from this seminar but a series of critical contacts was made and a network of contacts begun.

iii. From this starting point in 1989 the researcher groups at CSIRO and UNSW began a program of informal collaboration and a series of contacts were developed between themselves and the Australian Robot Association. The ARA mostly represented the manufacturing robotics industry and was active in facilitating cross-fertilisation of ideas.

The result of these contacts has been to develop a quite close ties within the robotics researcher community in Australia. This network of personal contacts has expedited considerably some aspects of technology transfer.

iv. From 1989 construction robotics work was included in the formal teaching program at UNSW at an undergraduate and graduate level and serious studies of robotic machinery and its potential was begun.

v. In around 1990 the first public lecture was given to the Australian Institution of Engineers on the topic of construction robotics.

vi. In 1991 the school of Civil Engineering joined with the Schools of mechanical, electrical engineering and Cognitive Sciences as an equal partner in an ambitious Robotics and Intelligent Machines project (RIM) to develop sensorily complex and problem solving robots.

vii. In March 1992 the first formal construction robotics laboratory in Australia was installed within the School of Civil Engineering at the UNSW through the acquisition of a Unimation 2500 series industrial robot. This machine has a 45 kg design load and is intended for specific construction oriented research. Prior to the acquisition of the Unimation machine work was undertaken in the School of Mechanical Engineering's robotics laboratories using a number of small payload robotic machines. This necessarily limited the scope of work that could be undertaken.

3.3. A Rationale For Robotics research in Australia.

A quite convincing argument can be advanced for leaving construction robotics development (which tends to be expensive) to rich industrial countries such as Germany, Japan and the USA. This would suggest that Australia should not have an indigenous robotics industry but should be an importer of technology.

On the other hand it can be argued that because of the special cultural, geographic and economic situation that prevail in the Southern Hemisphere and in Oceania in particular, the way these developments will manifest in Australia is likely to be quite different to the ways more industrialised or more population dense countries develop the same technology.

This diversity of development moreover is thought to be good in that it will enrich the range of robotics devices and systems that will ultimately become available to the industry.

Whilst both these points of view are considered to have merit the second is the philosophy currently being pursued. The author is fearful though that ultimately philosophy number 1 might be proven correct as Australia has been quite good historically at picking good new technologies but has failed in their exploitation because of lack of either will, development resources or commercial acumen.

4. A REVIEW OF ROBOTICS RELATED WORK IN AUSTRALIA

4.1 Categorisations of activity

Since the division between construction robotics and other forms of robotic research work in Australia is quite blurry, in the remainder of this article both the activities of the construction robotics industry and the wider robotics industry will be surveyed. This is because significant opportunities exist for the burgeoning building and construction robotics industry to take advantage of technology transfers across the borders of traditional and non-traditional robotics.

In discussion of the current state of the art of robotics research in Australia the following headings will be used to create some sort of coherent framework.

i. Concept development and educational activity
ii. Broad (Pre-product) Research And Development Activity.
iii. Commercial product and systems development

4.2 Concept Communication and Educational Activity

Apart from actual research and development activity an essential part of the process of gaining industrial acceptance of a technology and getting established engineers, contractors and the board members of companies interested in the technology and appreciative of its potential is education. It is essential that the concept of robotics as an idea and the current state of the art in capability terms be disseminated. Once this is done it is hopefully possible for the profession to make good and informed decisions about the technology and to select areas where application may be commercially appropriate.

Within Australia a process of education through the channels of undergraduate and graduate engineer education and through various seminars and exhibitions likely to be frequented by builders and contractors has begun. This process is likely to be quite a long one since not only does the R&D community need to become informed about robotics and its potential but busy practitioners also need to become aware of the technology and its pros and cons.

4.3 Broad (Pre-product) Research And Development Activity

4.3.1 Specific Construction Industry Related Research

A. Work underway at UNSW School of Civil Engineering

At UNSW a variety of strategic research areas are being addressed. These include:-

- Robot architecture and configuration research.
- Mechanical engineering aspects of construction robots.
- Sensor technology research.
- Real time control systems research.
- Artificial intelligence controller research.
- Computer vision research.
- Economic aspects of construction robots research.
- Social aspects of construction robots research.

- Research into the integration of Construction robots with CAD and CIM systems
- Autonomous and intelligent machines research.

The following projects at UNSW perhaps deserve special mention.

(a) Robotic arm research

A current major interest at UNSW is robotic arm research with both high dexterity and high lift capacity, large reach systems under study

(i) High Dexterity Robotic Arms

High dexterity robotic arms are high speed precision control systems that have a dexterity, flexibility and precision similar to that of the human arm. With high dexterity robotic arms one can do delicate and complex physical operations such as are required to work on high voltage power line insulators and to do up nuts and bolts. For certain applications these dexterous arms may be combined with large telescoping deployment booms. Control for these arms can be by telerobotic control arms or by full computer system.

(ii) Giant Sized Robotic Arms

Prototype large capacity machines have been tested and a number of very large machine forms are under development (Ref 2).

(b) Process Feasibility Studies

Economic and technical feasibility studies are currently being carried out into:-

- Fully automated vertical slipforming of structures using large capacity and reach on-deck robotic arms.
- Robotised shotcreting and tunnel lining with general purpose robtic arms.
- Automated steel reinforcement placement and tying.
- Concrete surface finishing with dexterous robotic arms equipped with finishing tools.
- Automated precast concrete quality control with robotic inspection test stations.

For this work some very specialised high speed interactive [3D] solids modelling computer software is under evaluation

B. Work Underway At CSIRO

At CSIRO Building, Construction and Engineering Division speciality research work is being done in the in the field of neural networks as applied to robotics problems, applied expert systems and computerised visual inspection systems.

A special interest at CSIRO is the sociological aspect of the introduction of advanced automation and construction robotics into the construction industry. Some most useful work is being done in this area (Ref 3).

4.3.2 General Mechatronics And Intelligent Machines Research

Most of the major Universities in Australia have some form of mechatronics or industrial robot teaching and research groups in their structures. This is normally placed in the mechanical or production engineering faculty.

Within these sections problems of inspection, welding robot control, vision systems, off line programming and computer integrated manufacture are studies.

Additional to Universities there are a number of specialised robotics research institutes and groups formed to address more specific issues and/or commercial problem areas.

Topics covered by these groups normally includes aspects of :-

- Automation and assembly theory
- Automatically guided and/or autonomous vehicles research.
- Geometrics and Kinetics
- Navigation and planning
- Localisation and sensing
- Control systems and strategies
- Applications software.
- New industrial applications
- Policy issues

Some very good work in the fields of robot navigation, imaging tactile sensors and environmental mapping is being done at these centres.

Within this broad framework of Universities and Research Institutes certain work deserve special mention in the context of this paper.

1. Monash University.
   Located in Melbourne, Monash University is a major centre for robotics work in Australia through its Intelligent Robotic Research Centre. Its speciality is robot environmental sensing systems and autonomous navigation (Ref 4).

2. University of Wollongong
   This organisation is active in the field of intelligent manufacturing systems and has done some most interesting work on things such as imaging tactile sensors for robot data acquisition.

3. The National Cooperative Research Centre in Robotics
   The Australian Government has recently set up a major cooperative research centre for advanced robotics research. This centre combines industry and researchers in joint project developments and has major Government funding.

4. University of Western Australia
   The University of Western Australia is located in the city of Perth and is world renowned for its work in advanced control systems and automated surface mapping and trajectory planning in connection with the problems of automated sheep shearing. (Ref 5). It has also done some excellent work in the field of computer vision and has solved the problem of reliable automated edge detection where the edge is fuzzy as in the case of wool on a sheep.

5. CSIRO Division of Manufacturing Technology
   The CSIRO is doing valuable work in the development of specialised technology in the field of line scan cameras and the development of custom VLSI signal processing chips.

6. CSIRO Division of Geomechanics
   The CSIRO has developed an interesting vehicle for mine emergency use called the NUMBAT. This vehicle is specially designed to survey coal mines and other where cave ins, fire or smoke is encountered. The machine is a single hulled, eight wheeled teleoperated vehicle controlled by fibre optic cable. Navigation is by stereo video and acoustic imaging (Ref 6)

7. UNSW Robotics And Intelligent Machines group.
   The UNSW RIM project has already been mentioned earlier in this article. The benefits of cross-disciplinary work have already become obvious though access

to professionals with different expertises and different hardware systems.

Interesting work has begun in the field of [3D] vision, real time operating systems, high speed real time data communication systems for video data and image processing. Benefits have also been realised already in the form of control of flexible or yielding structures such as may form the basis of construction robots.

4.4 Commercial Product and Systems Development

Whilst the commercial applications of constructional robotics are quite limited at the present the following areas being developed in conjunction with commercial interests.

1. Water and sewerage pipe inspection and repair systems
   The Melbourne Metropolitan Board of Works is actively developing a sewerage inspection and repair robot in conjunction with the CSIRO. This work is commercially sensitive and little detailed information about the project is available.

2. Concrete paving block laying robot.
   Interest has been expressed by the Australian Concrete Masonry Industry in supporting a project at UNSW involving the robotic laying of interlocking concrete paving blocks for large industrial hard-stand areas.

3. Large robotic manipulators
   UNSW has had some commercial backing from parties interested in the possibility of developing large general purpose construction manipulators.

4. High level falsework erection
   UNSW is working with a major specialist concrete formwork contractor interested in the automated erection of high falsework and scaffolding systems. The company's reason for doing this is basically for increased safety and productivity.

5. Road repair systems
   A Sydney company is actively marketing what one might loosely call a robotic arm based system for road pot hole repair. In this case a teleoperated boom with process based end effectors is mounted on a front of a truck which is driven to the damaged road location and the repair of the pot-hole executed quasi-automatically (Ref 7).

5. CONCLUSIONS

Whilst the general area of advanced automation in construction is undoubtedly still in its infancy, Australia has at least begun work in the field of constructional robotics and similar systems and has developed a small but quite broadly based program of work in this new discipline.

Because of its special cultural, geographic and economic situation the evolution of robotics in this country is already proving to be quite distinctive and unique. The approach generally as to the kinds of machines being considered and their mode of application is quite different from the style of robotic devices being proposed and developed elsewhere.

The task of introducing robotic technology wisely and in a socially and ecologically responsible way has clearly begun in Australia. It is a task that promises to be exiting and one which will pose many challenges to the whole research and engineering community and to the building industry which will be a future (perhaps unwilling) host to this new technology.

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