CONSTRUCTION AUTOMATION AND ROBOTICS IN AUSTRALIA - A STATE OF THE ART REPORT -

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ABSTRACT

In this paper a number of recent developments in the field of construction, mining and non-traditional robotics are reviewed. Details of a variety of commercial and prototype systems are provided and conclusions are drawn as to the existence of some limiting factors relative to the development of the field automation and robotics industry in Australia.

1. INTRODUCTION

The non-traditional robotics area, which barely existed even as a name a few years ago, is now an established area of activity within Australia and is emerging as the major growth area for robotics in this country. Many applications for non-traditional robotics in construction, mining, agriculture, shipbuilding, assets maintenance and the service industries have now been identified and are being actively pursued by a number of academic and industry groups.

This paper aims to provide a short review of some of the activity currently underway within Australia and then to follow this with some comments on emerging problems and future directions for the fledgling robtics industry.

2. AUTO-DRIVE AND AUTO-WORK MACHINES

One of the most interesting current development is the beginning introduction of intelligent and driverless trucks into the off-road materials haulage and surface mining industries. Unmanned trucks are now being put into full scale commercial service on Australia mining sites and a number of mining companies - in conjunction with Sydney University researchers- are looking at automatically controlled high-speed tramming of load-haul dump vehicles to improve on current tele-robotic control means which permit only quite low travel speeds. Australia is the first country in the world to take up large unmanned vehicle application in the civil and mining sector[1] and this technology is expected to spread rapidly. The economics of this type of technology in large scale earthmoving and mining applications is compelling[1].

In the perhaps more mundane industrial tractor control field, Billingsley at the University of Southern Queensland in conjunction with a number of agricultural machine manufactures is introducing low cost machine vision based steering systems for tractor control applications[2].

3. TELE-ROBOTICS

Tele-robotic control of earthmoving and mining equipment is now an established part of the underground machine operations scene in Australia. Large load-haul-dump vehicles are now being totally controlled by operators situated in control rooms on the surface. These operators direct large machines through machine vision and broad-band tele-communications links. Complex work patterns and very confined work situations are encountered. A number of safety and economic benefits accrue through the use of remotely controlled machinery

In a very interesting development of telerobotics that does not use broad-band communications links, the University of Western Australia has been researching the tele-operation of robotic equipment through the low speed communication facilities of the world wide Internet. Now, anyone in the world can log-on to a robot in distant Perth and control it to do tasks through limited channel-capacity vision control facilities. Work on the "robot connected to the web" is reported by Taylor[3]. The robot's world wide web address is http://telerobot.mech.uwa.edu.au/ and it has turned into an user interest phenomenon. In its first year of operation, the tele-robot had been accessed by more than 15,000 people from all over the world. Many of these have been stimulated and excited by the experience.

4. AUTOMATED INSPECTION AND ASSETS MONITORING SYSTEMS

The City of Melbourne in Victoria has a population of some 3 million people and thousands of kilometres of sewers and underground utility conduits. In a major new approach to assets management, Melbourne Water has developed (in conjunction with CSIRO -Australia's national research organisation) an artificial intelligence based sewer condition monitoring and inspection system. This system has been developed to meet all operational requirements of full scale use in a host of sewer-pipe types and underground conditions. The system uses a telerobotically operated in-pipe crawler vehicle with vision, acoustic and laser scanners[4].

The major Australian cities, Sydney and Melbourne, each have approximately 20,000 km of sewers ranging in diameter from 150 mm to above 4 metres. Worldwide, the total length is perhaps 100 times greater. Many of the sewers are old and their condition is not well known. Inspection and timely repair are being given increasing priority, due to incidents like a recent catastrophic failure which caused serious pollution and cost more than $20M in emergency repairs.

Traditionally, large sewers are inspected directly by staff who walk their length making a subjective assessment and perhaps measuring key features. Smaller sewers are inspected in a similar way but using remotely controlled video cameras carried through the sewer on small vehicles. These techniques are acceptable for detecting gross defects, but have limited reliability and consistency, due to lapses of operator concentration, operator inexperience, and the difficulty of deducing pipe condition from a 2D video image. This is especially true for more subtle defects which need to be accurately assessed to track progressive deterioration so that preventative maintenance may be scheduled when needed. Also, direct inspection staff are exposed to poisonous gases, biological hazards, and the risk of flash flooding in operating sewers.

The system developed establishes technology for non-subjective quantitative assessment of sewer condition. The approach involves measurement of the internal surface of the sewer using a scanner mounted on a remotely controlled vehicle which continuously traverses the sewer to build up a geometric model. The surface geometry is analysed by an AI-based system which identifies the type of defect and determines its severity. The AI system is being developed by a co-operating group at the CSIRO Division of Building, Construction and Engineering. It is expected that the geometric model will also be valuable for assessing repair options.

The system can carry either a laser scanner for use in drained pipes or a sonar scanner for flooded pipes. These systems have to be connected into a tightly sealed and extremely compact physical package for the particular access, environmental and operating requirements of operating sewers. The systems has been used for inspection of more than 4 km of sewer to date and shows great promise as a quantitative assets maintenance data gathering tool.

5. QUALITY ASSURANCE AND PHYSICAL TESTING

In a very impressive application of directed industrial robotics technology, the Hamersley Iron organisation in Western Australia has developed a multi-functional, fully robotised, on-site materials testing laboratory for the industrial quality control of bulk excavated materials[5]. The systems allows automatic crushing and sampling of bulk materials and the physical and chemical testing of samples. Full sample sieve analyses with accompanying complex testing such as such as sample weighing, oven drying and various types of chemical analysis are possible. The remote on-site testing facility is monitored operationally from a manned laboratory some 5 kilometres away. The system has been put into full commercial service and work 24 hrs per day 7 days a week and feeds data from QA testing into a integrated management information system. It is more than economical in comparison with manual testing and quality assurance methods and in addition has a number of technical, safety and workforce improvement advantages. The technology demonstrated is fully applicable to any forms of quarrying, aggregate production or bulk material quality control operations.

6. SIMULATION AND VIRTUAL PROTOTYPING TECHNOLOGY

In the conception, design and economic validation of potential robotic solutions to possible industrial problems as well as in tele-robotic system training, the availability of high fidelity real-time robotic system simulators with high quality graphics interfaces is of great potential value[6,7]. Such technology may even be considered a necessary system-design and virtual prototyping tool for construction work applications. In conjunction with industry partners, the University of N.S.W. is developing a range of earthmoving and construction plant and large scale mining equipment simulators for virtual reality testing of automation solutions and for the testing and development of artificial intelligence strategies for construction equipment.

7. MANIPULATOR SYSTEMS DEVELOPMENTS

A heavy load capacity modular manipulator systems developed by the author and previously reported in reference 8 is now being commercialised in Europe principally for the deployment off heavy tool systems such as diamond coring equipment and power saws (Fig 1). One application for this type of equipment is in the demolition of concrete and industrial process structures but the system has use in any application requiring the precise manoeuvring of heavy passive or active loads at large reaches or on conjunction with other field manipulator systems[9].

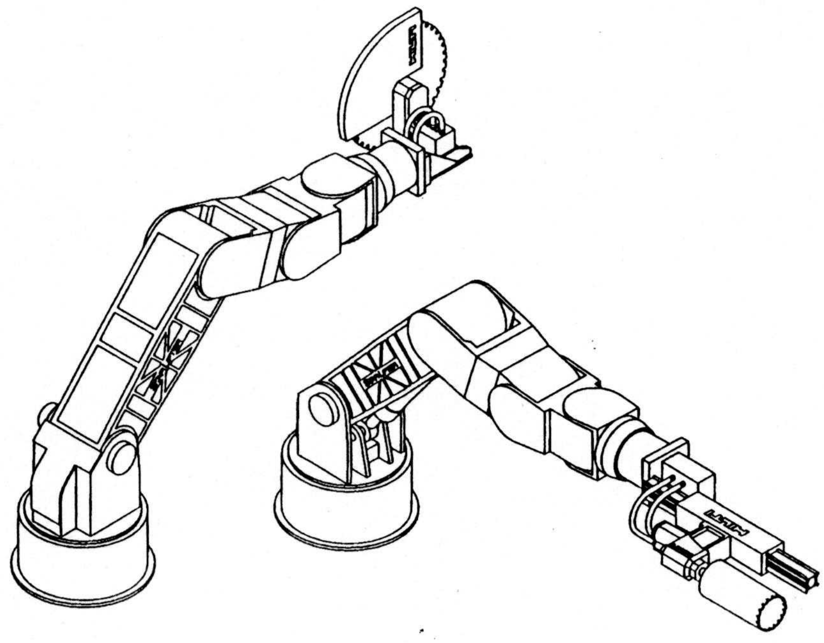

Figure 1- A robotic-action-head type electro-hydraulic manipulator for the deployment of heavy active-tool systems

In underground applications, the CSIRO in conjunction with the mining industry is developing an sophisticated electro-hydraulic manipulator for the automated installation of rock-bolts[10]. The system finds pre-drilled holes by use of an intelligent vision system.

8. ELEMENTAL TECHNOLOGIES AND SENSOR DEVELOPMENT

A number of groups are working around Australia to develop low cost sensors and ruggedised computer systems for field and mobile robotics applications.

* At the University of Sydney ruggedised, self- cooled real-time computer systems for mobile machine applications are being developed. Also, low cost inertial guidance systems, and 3D accelerometer systems are being developed for rugged field applications. Fail-safe safety technologies for both the sensing side and for the computing side of things has emerged as an important applications area and are being developed and tested.
* At the University of Wollongong (near Sydney), advanced acoustic point-by point and field imaging sensor technology is being developed[11-13]. This technology is defining the current state of the art in this field.

9. COST -EFFECTIVE CONSTRUCTION SYSTEMS DEVELOPMENT

A number of major contractor groups within Australia have now become interested in exploiting the productivity and time benefits potentially implicit in construction robotics and automation technology. Some serious research studies are now underway funded by contractor groups to assess the near term potential of robotics technology and to develop integrated construction systems that can capture those benefits. These studies are embracing such ideas as CIM and CIC and giving consideration to the immediate social and industrial environmental implications of such technology. Problems of corporate culture change are being investigated and development funding mechanisms sought. This latter problem is made difficult because of the highly projectised nature of contractor operations within Australia. Some of the difficulties projectisation makes in relation to R&D funding are discussed by the author in a paper later in this symposium[14]. Other features of the industry that will slow the uptake of robotics are a high degree of technological compartmentalism and current extensive sub-contracting practices.

10. HIGH IQ ROBOTIC SYSTEMS

Whilst the development of commercial unmanned and driverless vehicles - as discussed above- represent an undoubted major technical achievement, the IQ level of such systems is still extremely rudimentary. This limited problem solving capacity of these systems prevents them realising their full potential.

For more advanced and flexible systems a higher level of machine problems solving capacity is required. Some very interesting work is being done in this domain within Australia by the Universities and by the Defence Force Air-Operations Group. Their work addresses the general problem of high IQ robotics as well as issues of genuinely autonomous action[15-17]. Some work to develop theories for the collective action of individually autonomous machines is underway[15,18].

11. CONSTRUCTION CYBER-SPACE

Australia has an advanced telecommunications sector and good communications infrastructure. Using this technology, joint venture research work is being undertaken by the big communications company Telstra and the national research laboratory (CSIRO) to develop these facilities and to connect all aspects of construction activity together to make a "virtual village" or "virtual collective work-space". This area has been denoted by the developers as a new field that they call "teleconstruction"[19]. This technology offers many advantages in that base to field, field to base and within site physical distances factors can be eliminated. As well electronic integration of designers, constructors and suppliers can be accomplished. Productivity gains can be achieved through the use of distributed intelligence and distributed actors interactively working in "cyber-space".

12. OTHER TECHNICAL ACTIVITIES

Apart from the above, somewhat mainstream robotics activities, there are some speciality projects and work that has been completed and which is worth reporting upon here. One system is an electromagnetically "footed" mobile robot for shipbuilding and steel tank construction work[20]. Robots used in factories are typically fixed in position and process relatively small parts which are moved to and from them. Very large 'parts' such as buildings, storage tanks, ships, etc, are difficult or impossible to move and would in any case require a large robot which is expensive and inaccurate. Manufacturing and service operations on these 'parts' requires a different approach. A variety of mobile climbing robots have been developed, but they exhibit stop/start motion, and often have irregular paths. The robot developed by the CSIRO's manufacturing division provides the continuous motion and path capabilities needed for many manufacture and service tasks including welding, cutting, and sealant application. A prototype has been developed which can move continuously in curved paths over curved surfaces of any inclination. Mechanically, the robot, known as Mr Plod, comprises three main assemblies: a 'body' and two 'legs'. At least one leg always grips the surface so that the robot remains securely attached. The body is driven by motors which move and rotate the body by reacting against the gripping leg. Each leg grips the surface using three electromagnetic 'toes'.

13. REGULATORY AGENCY ACTION

The building and construction sector has the worst safety and occupation health record of any major industry in Australia. This generates large community costs and large. largely unseen, amounts of individual suffering. For some time the workers compensation insurers and regulatory agencies in Australia have been looking for new ways of reducing construction injuries and improving the occupational work environment. Robotic technology now appears to offer substantial potential in this area and is being actively investigated by regulatory agencies and safety legislators[21].

14. EDUCATIONAL AND TEACHING ACTIVITIES

Whilst most of the big Universities throughout Australia have classical industrial robotics as part of their education curriculum, only a few are significantly oriented towards the fields of non-traditional or field robotics. At the University of New South Wales in Sydney, construction robotics is now an established part of the undergraduate civil engineering student curriculum and the University of Sydney has a large segment on non-traditional robotics as part of its degree course in Mechatronics. The University of Southern Queensland has a speciality in agricultural robotics.

15. CONCLUSIONS

From this review one can perhaps conclude that the non-traditional robotics research community within Australia whilst small is highly active. This is despite being extremely under-resourced for the size and complexity of the task at hand. Overall though within Australia the area as a whole seems poised on the brink of industrial take-off - particularly in the mining and large scale civil earthworks sectors. This poses a major potential problem in that the rate of desired uptake by the user community is going to exceed by many times the ability of the providers to deliver. It is considered that the availability of trained construction roboticists and advanced sensor capable technical staff will soon prove a major impediment to providing the industry with sophisticated, well engineered and reliable field systems. The emerging industrial application will further create a virtually immediate demand for higher IQ robotic systems and smarter forms of machinery. Such systems are however beyond the capacity of the worldwide R&D community to deliver. This work can now be placed in front of the worldwide research community as a technically extremely difficult and sophisticated problem arena that needs to be put on the immediate agenda and given fundamental research support.

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