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ROBOTICS: THE PAST, THE PRESENT, AND THE FUTURE

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Abstract: *Robotics has experienced a major development in the application technology literature. Recent trends have shown a rise of interests in applications of robotics in manufacturing automation and information systems. Robotics and automation technology is being widely used for waste management, hazardous activities, industrial applications in the oil and gas industry, for marine cable route surveys, near shore nautical charting and military surveys pipeline inspection and monitoring of sensitive coastal environments, among others. Despite the immense opportunities for growth, the robotics field has suffered a high rate of disintegration across studies. The literature could be described as spit with studies scattered in different journals. The need to have an integrated literature on robotics therefore becomes important. This work is aimed at filling the gap. The holistic literature presented here aims to increase our understanding in this widely expanding field and stimulate a higher level of proliferation of research articles in the field.*
Key words: *robotics, automation, and robotics application, literature review*

1. INTRODUCTION

The amazing development in the field of robotics in the past few years has opened up totally new and challenging research areas (Trevelyan, 1997; Engelberger, 2001). In fact, the developments in the field of robotics in the 20th century has prompted observers to predict the use of robots in unusual places (Kochan, 2002), for dangerous tasks (Hollingum, 1999), and in space exploration (Weisbin, 1997; Virk, 1997). Although these predictions have not been fulfilled to a large extent, there is a high possibility of success since technology has been experienced to have an explosive breakthrough. Hence, these predictions are promising.

The knowledge pool built up in this field has been enormous thus creating significant economic, social and cultural benefits to the world at large (Testa, 1995; Tachi, 1999). Although the use of robots is fascinating and very productive, the issue of the huge investment needed to have robotics in place and the high value of maintenance cost required to keep the system operating is retrogressive in expanding the concept to small scale enterprises (SMEs). It should therefore interest researchers to develop robotics that could manageably fit into the SMEs (Cipolla et al., 1996; Biros, 2002). This therefore calls for a radical change in the design and construction of robots, particularly for SMEs in developing countries (Alkhafaji, 1991). Along this argument, Kim et al. (1990) investigated into the investment decisions on the development of robotics technology. The literature on robotics is wide, covering diverse areas in technological education and training, construction systems, industrial applications, healthcare, among others (Kochan, 2001a,b; Murphy 2001; and Arkin, 2001). The following section is a brief review of the contributions of studies to the robotics literature.

2. PREVIOUS RESEARCH

2.1 Robotics in Healthcare Systems

The contributions of robotics to the healthcare system could be described as unprecedented, saving several millions of lives due to the precision introduced by the robotics technology during healthcare. Thus, human errors that may result in loss of lives during surgical operation are avoided. Application of robots in healthcare systems is having a compelling impact on healthcare by improving efficiency in the operating room (OR) with better communications, streamlined networks and effective personnel utilization, increasing the number of procedures that can be performed in a minimally invasive fashion for reduced patient pain, trauma and recovery time; and enabling new procedures that would otherwise be impossible to perform due to human limitation (Wright, 2001).

The revolutionary surgical technology offered by robot is extensively dealt with in the classic study of Broeders and Ruurda (2001) who investigated into the concept of Laparoscopy in surgery. The introduction of robotics to patient treatment solved a seemingly unresolved problem – reduced dexterity – through intuitive surgical "Davinci" systems. Cavus et al. (2003) gave support to the study by Broeders and Ruurda (2001) by probing deeply into the telesurgery aspect of healthcare system with an investigation on the second generation Berkeley/UCSF Laparoscopic telesurgical workstation. The study enhanced the dexterity and sensation of regular and minimally invasive surgery through using millimetre-scale robotic manipulators under the control of the surgeon. The investigation introduced kinematic and control issues and the presentation of in vitro-experimental evaluation results.

The future holds much promise for robotic knowledge development and the expansion in the field if we realize and exploit what Kochan (2002) found out about robotics. However researchers and developers must understand the technology requirement for robotic surgery.

In another study, Wright (2001) points out that the introduction of robotics in healthcare necessitates careful evaluation of the technology along several criteria: assessing the appropriateness of the technology or equipment under consideration: OR readiness; procedural compatibility; precision and dexterity enhancement; and open architecture and upgradeability. Evaluating along these four cornerstones helps ensure the equipment or technology will meet the feasibility, accuracy, utilization, system longevity, patient safety and surgeon/OR team benefits required by today's OR environment and staff (Wright, 2001). Unfortunately, surgeon and other medical professionals may not have the technical knowledge and experience in the design, construction and implementation

of robots in operating environments. This problem can be resolved through a multidisciplinary research effort which includes surgeons, engineers, and psychologists, among others. Thus, there is a call for collaboration among professions – in order to have the "perfect robots" for the operating environments (Hollingum, 2001).

2.2 Robotics in the Industry

There are several dozens of papers in the past few years on the applications of robotics to the industry. The case investigated by Spencer (1996) is a good example. The survey carried out explored the extent of implementation of robotics in the footwear industry. In particular they focused on the application of advanced manufacturing techniques and automation technologies for production activities. They found out how many manufacturers in an environment have turned to robotics and automation for more reliable manufacturing system solutions. The study, emphasizing on the robotics integration and system-level products specifically targeted for footwear manufacturing operation provided by three specialist companies; ACTIS Engineering, DESMA and Intelligent Machine Corporation.

The applications of robotics in the industry seem to have a strong base in the food industry (Wallin, 1995; Quinet, 1995). The strong reason behind this may be due to the repetitive nature of many food production systems. Another reason may be the need for more efficiency and productivity in food production environments where intensive pressure and temperature under which production is carried out may not allow human beings to perform at the optima, and may also be injurious to human health.

The wide application of robotics in the food industry must have motivated Walling (1995) to review the use of robotics and opportunities in the food and drinks industry. The review is based on a report commissioned by MAFF (Ministry of Agriculture, Fisheries and Food). It outlines trends and changes, robot sales figures in the food market, problem areas and technology limitation. It further stresses the need for adequate research projects to fully realize the potential of robotic systems so that known technology can be applied to specific food – manufacturing solutions. It concludes that there is a huge potential for the development of automated systems for the food industry, however technologies need to be integrated to enable specific food machine to be developed which meet the necessary hygiene and food industries requirements.

Still on research in the food industry, Tillett (1995) examines the effectiveness of using expensive robotics equipment in the food industry where profit margins are low and labour is less expensive than in other industries. The study looks at the work undertaken at the Silsoe Research Institute into developing appropriate low-cost technology for basic food applications. The project discussed include robotic teat cups for milking cows and a robotic mushroom harvesting; both using pneumatic power transmission. It concludes that food production will become an important application for robotics when it is generally accepted as cost effective.

Another paper on the food industry research was presented by Fitzpatrick (1997) who investigated into the post-production activities with an investigation into the several characteristics of the first unmanned harvester - Robot Windrower. The study describes how lunar rover and terrestrial military vehicle technology is combined to define two core technologies for mobile agricultural equipment - fieldNav, the digital machine; and fieldhand, the digital operator. Outlines the hardware and software used; standard and custom components used for safety and customized electronics; modifications for driver by-wire; the event-driven, behaviour-based architecture (SAUSAGES); sensing for crop line tracking; other detectors, trackers and GPS used for guidance. It explains the benefits of such automation to agriculture and what the future holds for commercialization of Demeter.

Research on robots applications in industrial organisations also extends to occupational health and safety control, applications in dynamic assembly systems and its use in ship building. In occupational health and safety control, McAlinden (1995) considers the use of robotics in the workplace as a means of protecting workers from exposures to hazardous substances, environment and physical agents. The paper gives example of robots being used to handle radioactive material and working in the high dust exposure atmosphere of a plastic factory.

In dynamic robots assembly systems, Su et. al (1998) finds the best placement sequence and magazine assignment. Before conducting the research, scholars utilized the fixed coordinate of placement points and magazine of the travelling salesman problem (TSP) method to sequence the placement points after the magazine has been arbitrarily assigned. This hinges on the fact that robotics travel routing should be based on a relative coordinate because the robotics, board and magazine simultaneously move at different speeds during assembling. Consequently, the coordinates of placement point and magazine are constantly changing. The proposed approach can arrange the placement sequence and assign the magazine slots to yield a performance better than the conventional one. The results presented also demonstrate that the larger the number of placement points and/or part numbers, the better the performance.

2.3 Robotics in the Construction Industry

In the construction industry research on robotics has been investigated into wide varieties of areas. The automation and robotics, the interdependence of design and construction systems; and the enabling technology for a masonry building advanced robot are representative aspects. In the work by Cusack (1994), an examination of the potential for introducing robots into the Construction Company was made. The paper outlines some of the problems to be tackled including the technical and organizational problems of site layouts and the role of automation and robotics in construction. It further discussed the advantages of using task-specific robots and the development of mechatronics. Emphasis was made on the need for the development of CAD in architecture and construction, private design description of a building to make available the necessary information about the developing building geometry on the construction site. However, Chamberlain (1994) initiated a research program into the use of robotics in masonry building. The four main objectives of the project were to establish the requirements for the application of robotics in masonry construction; construct a prototype robot; develop the operation software system; and evaluate suitable blocks for construction using robots. The work describes the construction of the prototype robot cell and the research methods used and conclude that combining the research findings with work elsewhere it should be possible to achieve a commercially viable robotic solution for masonry and similar tasks on the construction site.

In ship building robots technology has been extensively applied in welding processing (Dalton, 1997; Sorenti,

1997). An investigation by Sorenti (1997) on the efficiency of robotic welding for shipyards describes how virtual reality simulation technology is being used and developed to support the design, and programming, of large-scale robots are welding cells in two of the world's largest and most modern shipyards. GRASP-VRI is a shipbuilding-specific software simulation and offline-programming tool, developed as part of a highly productive method for rapidly crating arc-welding programs for robots. The work describes the integrated program creation concept that uses pre-defined, parametric libraries of generic arc-welding tasks that were created and verified prior to, and during, cell commissioning. The author concluded that the approach is applicable to other robotics applications such as cutting, gluing and inspection.

2.4 Education and Training on Robot Technology

There is a wide array of studies on robotics education and training (Kochan, 1996; Davies, 1994). A few of these studies are discussed here. A primary study on this aspect is credited to Taylor (1996) who examines the development of courses in robotics and advanced automation at UK Universities and describes the relationship between industry, research and the courses. The study looks in detail at undergraduate courses offered by the universities of Hull, Bristol, Plymouth and leads metropolitan university. It describes the pioneering postgraduate course at Cranfield University and states that the collaboration between these Universities and industry and the support this collaboration provides has been essential for the viability of the courses. It concludes that the future is bright for these courses so long as they are well presented to potential students and the industrial sector remains committed.

In Robinson (1996), the focus is on strategy for development. The paper examines the importance of training engineers, particularly in the field of robotics. It discusses the paucity of courses at universities and compares this with the greater number of courses at technical colleges. It explains factors that inhibit the development of relevant courses; and discusses specific course aims, recent development of relevant courses; and discusses specific course aims, recent developments, and practical issues.

2.5 General aspects of the Literature

There are several studies that may not be classified under any of the works discussed above but could be treated under the general umbrella of robotics (Maxwell, 1998; Hollingum, 1997). A body of research treats the extent of development of robotics technology in different nations. The coverage areas are not limited to the industry but expand to the academia and other areas. Primarily, documentation has been made on general applications on robots in Finland (Monkman,1994), United States of America (USA) (Masory, 1996), South-East Asia (Shirinzadeh, 1996), and the United Kingdom (U.K) (Wilson, 1997).

The work by Monkman (1994) reports on the 1992 finish Robotics conference in Helsinki that focused on the application of robotics in Finland.

The areas covered include medical robotics, advanced flexible robotic systems for small batch manufacturing, and automated laboratory systems and waste disposal systems. Hollingum (1997) shows how two events pointed the way for the U.K to put itself in the Vanguard of the next stage of intelligent robotics development, the first came the publication of a report *Technology and Market Review of the Robotics Sector* which studied the state and prospects of robotics in seven sectors of UK industry and proposed that special efforts, including demonstrator projects should be focused first on the food industry sector and then on the medical sector. The second event was the launch of SILVER SIG, a special Interest Group for intelligent vehicles and Robotics. A major participant in Silver is the Defense Evaluation and Research Agency. DERA, which is committed to linking commercial Industry with government research – in this case in the development of intelligent vehicles.

3. CONCLUSIONS AND FUTURE RESEARCH

Generally, the robotics literature is composed of a wide away of studies in diverse areas, notably industrial applications, healthcare, construction systems and technological education and training, among others. We have presented the robotics literature in an integrated form. As such, our work seems beneficial to the robotics and the wider automation research community. The work is motivated by the urgent need for by researchers to understand what others are doing in the field. Thus, will we not continue to be workers in the *Tower of Babel* researching into an area without a full understanding of what others were doing with us.

From the findings of this study, it is recommended that many areas warrant investigations. Having recorded some degree of success in education and training, much needs to be done in understanding the various concepts embedded in robotics. From the author's experience in electronics spreadsheet application in teaching undergraduate students, there seems to be no documentation source on the use of spreadsheets in understanding the important aspects of robotics. Intensive studies on "what - if" analysis could be carried out on the robots' anthropometric characteristics such that the awareness level of the use of spreadsheets for robotics analysis could increase.

For example, very little (if any) applications of spreadsheets in robotics are made in West Africa. Unfortunately, there is a large pool of intellectuals interested in related studies. Simulation projects on robotics could be helpful in promoting knowledge and training in this part of the world. The same may be true for other developing countries of the world.

A top priority research is the development of robotics technology for small-scale enterprises (SMEs) in view of the huge investments that the adoption of robotics technology in SMEs implies.

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