NEURAL NETWORK APPLICATIONS IN THE DEVELOPMENT OF ARTIFICIAL INTELLIGENCE MODULES FOR A PATIENT LIFTING ROBOT

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DECLARATION

The materials in this thesis are original except for quotations, excerpts, summaries and references, which have been duly acknowledged.

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ABSTRACT

One of the challenges that hospital nurses face is to stay fit and healthy with the heavy workload they have to endure on their day-to-day life. The workload includes the task of patient lifting and transferring. Most nurses suffer from lower back pain due to excessive load exerted on to their lumbar spine during patient lifting and transferring. A patient lifting robot is proposed and conceptually designed in this research to solve this problem. The patient lifting robot is a semi-automatic, wheeled, bed-type robot which is modeled according to the "three-men patient lifting technique". The robot arm consists of three segments. This arm is extendable or retractable and is responsible for taking and lifting the patient from bed. Each of these segments has a conveyor belting system. The robot goes near the bed and identifies the location of patient on the bed, inserts its arm between the bed and the patient, takes the patient through the sets of conveyor belts and lifts the patient from the bed. The robot is equipped with a set of sensors which forms an integral part of the control system. In addition, safety to the patient has to be ensured while transferring the patient to the robot arm and then lifting. Hence, these complex control abilities of robot are possible only by using artificial intelligence techniques. The entire control and intelligence system of the robot consists of five (5) modules, namely (i) the patient position tracking module, (ii) the automatic procedure sequencing module, (iii) the fail safe and recovery module, (iv) the danger monitoring module, and (v) the motor speed and trajectory module. The motor speed and trajectory module is developed in a separate research and is considered as a black box in the context of this research work. This research discusses the importance of each of these modules and how they are interrelated. The modules are developed using neural networks to perform their specific functions. A carefully designed data base corresponding to each of the modules is created. These data are used for training the various neural networks. The entire function of the patient lifting robot is realized by these networks. The robotic functions are constantly monitored by nurses. Provisions are incorporated for the nurses to change any sequence of robot operations when required or when malfunctions are expected. All the neural networks of the robot's intelligence system are trained for their required tasks and tested for their successful functioning using the designed data base.

ABSTRAK

APLIKASI RANGKAIAN NEURAL DALAM PERKEMBANGAN MODUL-MODUL KECERDIKAN BUATAN UNTUK ROBOT MEMINDAH PESAKIT

Salah satu daripada rintangan bagi para jururawat adalah untuk menjaga kesihatan mereka dengan amaun kerja yang perlu mereka pikul dalam tugasan harian mereka. Salah satu daripada tugas harian mereka adalah mendukung dan memindah pesakit. Kebanyakan jururawat menghadapi masalah kesakitan tulang belakang akibat tekanan keterlaluan yang dikenakan ke atas tulang belakang dalam proses pemindahan pesakit. Bagi menangani masalah ini, sebuah robot memindah pesakit telah dicadangkan. Reka bentuk robot ini dibentangkan dalam penyelidikan ini. Robot memindah pesakit ini adalah sebuah robot separuh automatik. Robot ini berbentuk seperti katil beroda, dan dimodelkan berasaskan teknik "three-men lift". *Lengan robot terdiri daripada tiga segmen. Lengan ini boleh dipanjangkan dan ditarik balik, dan pergerakan ini digunakan untuk memindah pesakit dari katil ke lengan robot. Setiap segmen lengan mempunyai system konveyor yang tersendiri. Robot akan mendekati katil dan mengecam lokasi pesakit di atas katil. Seterusnya, robot akan menyelitkan lengan di antara katil dan pesakit, dan mengalih pesakit tersebut ke atas lengan robot dengan pergerakan tali konveyor yang telah ditetapkan. Robot tersebut dilengkapi dengan alat-alat sensor. Alat-alat sensor ini adalah bahagian yang amat penting dalam membentuk sistem mengawal robot. Keselamatan pesakit semasa proses pemindahan adalah amat penting. Oleh yang demikian, kecerdikan buatan diaplikasikan dalam sistem pengawalan yang kompleks ini, bagi mencapai tujuan yang diingini. Sistem pengawalan dan kecerdikan dibahagikan kepada lima (5) modul, iaitu (i) modul pengesanan lokasi pesakit (pada lengan robot), (ii) modul penyusunan prosedur secara automatik, (iii) modul pengagalan secara selamat dan pemulihan, (iv) modul pengesanan bahaya, dan (v) modul pengawalan halaju pergerakan motor. Modul pengawalan halaju pergerakan motor tertakluk kepada penyelidikan yang berlainan, maka modul ini dianggap sebagai satu 'kotak hitam' dalam pembentangan hasil kerja dalam tesis ini. Penyelidikan ini membincangkan tentang kepentingan setiap modul tersebut, dan bagaimana modul-modul tersebut akan dirangkaikan dalam sistem pengawalan dan kecerdikan robot ini. Modul-modul ini dikembangkan dengan mengunakan rangkaian neural mereka yang eksklusif bagi fungsi mereka yang tersendiri. Sebuah pangkalan data bagi penciptaan setiap modul ini direka dengan teliti, berasaskan fungsi modul-modul tersebut. Pangkalan data ini digunakan semasa proses latihan rangkaian neural. Fungsi keseluruhan bagi proses memindah pesakit ini direalisasikan melalui rangkaian-rangkaian ini. Bekalan yang secukupnya akan disediakan bagi para jururawat bagi membuat penukaran dalam proses sekiranya diperlukan atau semasa kegagalan dalam jangkaan. Semua rangkaian neural dalam sistem kercerdikan robot telah dilatih bagi fungsi yang telah ditetapkan, dan kecekapannya juga telah diuji dengan menggunakan pangkalan data yang telah diperkembangkan.*

KEYWORDS

Keywords:

Medical Robotics, Artificial Intelligence, Neural Network Application, Patient Lifting, Nurses Assistance Robot

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ABBREVIATIONS

ANN	Artificial Neural Network
AI	Artificial Intelligence
NN	Neural Network
BP	Back-Propagation
PIC	Peripheral Interface Controller
BCD	Binary Coded Decimal
CS	Conveyor Sequence
L	Load/Loading
U	Unload/Unloading
P	Position
S	Status/State
Seq.	Sequence
Conv.	Conveyor
MSE	Mean Square Error
FR	Fail Recovery

SYMBOLS

k	Number of samples
$u_j(n)$	Induced local field of the neuron *j*
y_j	Vector of activation function for neuron *j*
$\Delta w_{ji}(n)$	Weight correction
η	Learning rate parameter
$\delta_j(n)$	Local gradient of neuron *j*
$y_j(n)$	Input signal of neuron *j*

CHAPTER 1

INTRODUCTION

1.1 Robotics in Medical Applications

Over the past decades, robotic technology has been employed more and more in medical fields. The main objective of medical robotics is to develop a partnership between man and machine, which takes the advantage of the capabilities of both to enhance the performance of a task. The medical robotic technology provides surgeons with better perception, decision and action on their patients with the additional tools to work for them [Lavallee, *et. al.*, 1992].

A major characteristic of a medical robotic system is that it works in a human environment with the similar advantages that an industrial robot provides. In an industrial environment, the robots are usually isolated from the trained workers who are responsible for their operation [Duchemin, *et. al.*, 2004]. In a hospital or a health care centre, where medical robots operate, these robots come in contact with the patient, medical staff and materials. It is highly critical that any failure of medical robot will not affect the credibility of surgeons and other medical staff and does not create a dangerous state to patients. Therefore, it is very important that the medical robots must function safely, and with high reliability and dependability [Nagarajan, 2002].

One of the popular applications of robotic technology in the medical field is in the surgery. The first area of application of surgical robotics was in orthopaedic surgeries, that utilizes the advantage of the high precision and high repeatability of robots [Dario and Menciassi, 2002]. Later developments expand to knee replacement surgeries, hip replacement surgeries, laparoscopic minimal invasive surgery, and also in other areas where robotic applications were possible. Robotic technology is also used in tele-surgeries, where a surgeon performs a surgery on the patient from a remote place [Ghodoussi, *et. al.*, 2002]. With the revolution in image processing and on-going miniaturisation of components, and also in the vast development of telecommunication systems, more opportunities are opened up for further research and development, that will improve the currently available technologies to benefit more patients.

Another area in the medical field where robotic technology has been widely utilized is in rehabilitation efforts. The development of robotics in rehabilitative applications has begun in the early 1960's [Hillman, 2003]. The earliest works focused on the development of manipulators for orthosis/exoskeleton which helps in moving user's paralyzed arm. Research and development in this area has expanded to the development of prosthetic arms, smart wheelchairs, mobile robots, physical supporting systems, and devices that assist therapeutic intervention.

Another area of application of robotics in the medical field is to provide service in the hospital and hospital laboratories. Such robots are known as the service robots. These robots are generally used in inventory management, record management, facility maintenance, and, transportation [Dario, *et. al.*, 1996]. The stationary robots are used extensively in laboratories to carry out the testing and analysis of specimen, as well as selecting and delivering medicines in accordance to prescriptions in a hospital pharmacy. Another variety of service robots are used extensively to carry and transport items such as medicine, test samples, hospital waste and food items from one location to another. The patient lifting robot falls into the category of service robots, as it provides assistance to nurses in lifting and transferring patients from one location to another.

1.2 Application of Artificial Intelligence in Robotics

One of the areas of research that has been generating a lot of interest over the past two decades is the development of Artificial Neural Networks (ANN) and its applications in highly complex systems. The robotics community has traditionally focused on problems such as the sensing, which includes visual recognition, force sensing, and proximity sensing, the manipulation, which includes planning of the motion of arms through space and computing angles from which a manipulator can grasp an object, and the locomotion, which includes control systems that are developed for a wide variation of movements. The AI community, on the other hand, considers the more abstract problems of a system reasoning about its environment, solving problems such as the planning of complex sequences of actions to achieve a goal and efficiently determining the outcomes of a set of principles [Kaelbling, 1988].

The pairing of AI and robotics results in a family of intelligent machines. These machines have physical interaction with its environment which behaves with more flexibility and smartness, compared to the typical industrial robots. The incorporation of AI in robotics opens up wide possibilities to stretch the limits of the conventional techniques, and encourages the integration of more diverse subsystems. With the available technology in AI, the integration of the disparate and contradictory information gathered by the sensors integrated with the robots is made possible, and the robust planning of series of actions for the end effectors can be developed.

One of the earliest intelligent robot was Shakey, developed by SRI International [Agre, 1985], which was built in the late 1960's. Shakey was incorporated with a computer vision system and laser range-finder, and this enabled the action of pushing blocks from room to room. This research inspired many other important AI systems and techniques, including the STRIPS planning system [Kaelbling, 1988]. The STRIPS planning system is used to determine a sequence of actions to be executed by the robot, to achieve a goal. There are three vital descriptions required for this planning system which is the robot's situation, the goal situation and the effects of all the actions the robot is able to perform. In case of any failure, the robot would retry with the current known situations. This technique inspired the development of the micro-operators. The micro-operators generate sequences of the atomic actions available to the robot. The planning system works more efficiently when the generalized version of the previous plans made are stored in its memory. These techniques, however, revolves around a known environment, which was then impractical for real-life applications.

Planning and action modeling is one of the largest areas of research in the development of intelligent robots. The method used in Shakey has since been extensively studied and improvised by the AI community. One of the biggest issues in efforts to achieve a practical solution is that the planning system is still inflexible, hence it is impractical in a dynamic working environment. This is because the robot may not recognize the current situation in the environment and may invalidate its plans; in cases where the robot is ignorant of the changes of its environment while it is planning on the next move, it may be hazardous. Some researchers have chosen to focus on developing building mechanisms for routine behavior rather than system planning, while some focus on developing planning systems that are constantly updating and learning as they operate. Brooks developed a system which is built up with hierarchically formed component behaviors of increasing degrees of sophistication [Brooks, 1985]. This system is widely applied in solving problems for manipulator control and mobile robots in unknown environments.

Another area of research in incorporating AI into robotics is the development of robotic vision, which focuses on the analysis of an image that is previously unknown to the robot what the image represents. More often, image processing is time-consuming and complex. However, when the system has prior knowledge on what is expected, and then it improves vastly the efficiency of the vision system, which is the basis of the model-based vision. The model-based vision has been widely applied in industrial robotics, where it is required to locate a position and orientation of an object. Another widely used method is to acquire visual information from a low-level visual procedure through the sensors attached to the robot system, such as cameras or through the depth-from-motion method. This technique is especially useful for applications where the knowledge of a distance is essential to the operation of the system [Brooks, *et al.*, 1987].

The development of a highly dynamic intelligent system is amongst the main research areas in recent times, as well as incorporating human reasoning ability into a robot system. The interest in this area sparked the interest of studies in neural

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