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TO MAP 3 DOF WAIST POWER ASSISTIVE ROBOT MOTION USING NEURAL NETWORK

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A report submitted in partial fulfillment of the requirements for the degree of Bachelor of Mechtronic Engineering with Honours

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“I declare that this report entitle “TO MAP 3 DOF WAIST POWER ASSISTIVE ROBOT MOTION USING NEURAL NETWORK” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.”

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ABSTRACT

Wearable robot such as an exoskeleton can increase the performance of a user. It can be used to enhance the strength or improve the user endurance through various means. There are numerous type of exoskeleton with various design and waist assistive robot is one of it. Waist power assistive exoskeleton can be used to improve muscle endurance of the user by providing support torque at the back. To control exoskeleton, desired characteristic to sense physical motion of human is needed. There are several studies that use Electromyography (EMG) sensor to detect human intention. However, it is complicated and expensive. Thus, by using force sensor resistance, the measure of external muscle pressure is simple, cheaper, and has reliable way of sensing and giving feedback of muscle. The mapping method was proposed to map the exoskeleton according to the user's intention. With the feature extraction and classification using Back-propagation neural network (BPN), the Force Sensor Resistrance (FSR)-Angle model was constructed to be used for pattern recognition. One healthy subject performed forward bending, forward bending to the right and to the left. The FSR signals of the forces from the front and the back of the subject body were collected. The mapping scheme reliability were evaluated in the experiments. The results indicated that mapping using BPN with 2 hidden layer shows better performance compared to 3 hidden layer BPN.

ABSTRAK

Robot boleh pakai seperti kulit luar boleh meningkatkan prestasi pengguna. Ia boleh digunakan untuk meningkatkan kekuatan atau meningkatkan daya tahan pengguna melalui pelbagai cara. Terdapat pelbagai jenis rekaan robot kulit luar dan Waist Power Assistive Robot adalah salah satu daripadanya. Pinggang kuasa bantuan kulit luar boleh digunakan untuk meningkatkan daya tahan otot pengguna dengan menyediakan sokongan tork di belakang. Mengawal kulit luar, ciri-ciri yang dikehendaki untuk mengesan gerakan fizikal manusia diperlukan. Terdapat beberapa kajian yang menggunakan Electromyography (EMG) sensor untuk mengesan niat manusia. Walau bagaimanapun, adalah rumit dan mahal. Oleh itu, dengan menggunakan daya rintangan sensor, ukuran tekanan otot luaran adalah mudah, murah, dan mempunyai cara yang boleh dipercayai daripada penderiaan dan memberi maklum balas otot. Kaedah pemetaan telah dicadangkan untuk memetakan kulit luar mengikut niat pengguna. Dengan pengekstrakan ciri dan klasifikasi menggunakan Back-propagation neural network (BPN), Force Sensor Resistance (FSR) model - Angle telah dibina untuk digunakan bagi pengiktirafan corak. Satu subjek yang sihat dipilih untuk melakukan pergerakan tunduk ke hadapan, tunduk kehadapan ke kanan dan ke kiri. Isyarat FSR tekanan dari depan dan belakang badan subjek dikumpulkan. Kebolehpercayaan skim pemetaan telah dinilai dalam eksperimen. Keputusan menunjukkan bahawa menggunakan pemetaan BPN dengan 2 lapisan tersembunyi menunjukkan prestasi yang lebih baik berbanding dengan 3 lapisan tersembunyi BPN.

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CHAPTER 1

INTRODUCTION

1.1 Motivation

We have all seen exoskeletons in some of the popular science fiction, even if we did not know what they were called. The exoskeleton robot is a wearable robot which consist primarily of an outer framework worn by a person. The main function of a powered exoskeleton is to assist the wearer movement. There were a talk about robotic exoskeleton that give people almost supernatural lifting skills, but these tend to be confined to labs or science fiction. In South Korea, Daewoo has been testing a suits that let shipyard workers carry object as heavy as 66 pounds [1]. This kind of development has introduced a new solution to help human to lift heavy object.

In the developed countries, there are about 12 to 53 new spinal injuries per million population every year. The incidence is expected to be much higher in Malaysia for example, in Sarawak General Hospital Neurosurgical service, every month there is a case of spine injuries for patients admitted with head injuries [2]. Often in the hospital, doctors told hundreds of thousands of people with spinal cord injuries, “You will never walk again” [3]. There are some other cases where patients suffers from bulging or ruptured disk, osteoarthritis, skeletal irregularities or osteoporosis they will have problem moving their own bodies. The invention of exoskeleton robot has given a new hope for these patients.

1.2 Problem statement

Nowadays there are many researchers studying and developing various kind of man-made machine systems. The user requires frequent and repetitive functional training for rehabilitation and to help people with disabilities perform daily life activities exoskeleton robot is the most suitable tool to be used. The ideal situation is where the user can properly control exoskeleton, desired characteristic to detect physical motion of human is needed. The controllability take a consideration of flexible and smooth motion generation, safety and responsiveness. However, to drive the exoskeleton according to the user intention acquire an accurate and reliable mapping concept. The mapping method need to be excellent to perform exoskeleton efficiently. The method propose to map the exoskeleton motion is by using neural network as this method may surpass other mapping method. The performance of neural network analysis will be investigated throughout this project.

1.3 Objective

The main objective for this research are

1) To map 3 DOF waist power assistive robot motion using Neural Network
2) To test the performance of mapping in terms of accuracy and precision

1.4 Scopes

This project will covers only on:

1. Mapping 3 DOF motion of an exoskeleton waist power assistive robot using neural network
2. Analysis of waist power assistive robot motion using back propagation of artificial neural network
3. During the experiment, the subject is standing straight doing three type of motion
4. There are only three types of motion involve during experiment which is bending forward, bending forward right, and bending forward left.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In 1960s, United States Military and General Electric has invented mobile machine coordinated with human movement named Hardiman [4]. It was the first genuine exoskeleton robot that can lift 110kg item much the same as lifted of 4.5 kg. It is powered by hydraulics and electricity. An exoskeleton is normally characterized as an outer frame mechanism together with a joint and links, similar to the human body. When human suited up the exoskeleton, torques can be transmits from actuator through a rigid exoskeleton links to the human joint.

There are many methods to control an exoskeleton robot movement. Although this literature will covers wide variety of such methods, this review will focus on one major theme which emerge repeatedly throughout the literature review. The theme involved is mapping of an exoskeleton motion. Even though the literature presents the themes in a variety of context, this paper will primarily emphasis on the implementation of neural network in mapping the exoskeleton robot motion using inertial sensor and force sensor resistance.

2.2 Control System

To control the movement of an exoskeleton, a great control strategy is obliged to be executed so that the user can control the exoskeleton easily. There are numerous sorts of uses for exoskeletons for instance like power augmentation or rehabilitation which makes improvement of a generalized control technique for all exoskeleton would be very challenging. Thus, a suitable control plan for the application is a key to make the exoskeleton to operate smoothly.

From previous study, many of their control strategy built on motion intent recognition. This sort of control strategy determines user's intention using combination of sensors and mapping method to generate appropriate trajectories with the exoskeleton.

2.3 Sensory system

The symbiotic connection between humans and exoskeleton robots has exceeds the boundaries of simple physical interaction. It involves smart sensors, actuators, algorithms and control strategies capable of gathering and decoding complex human physiological occurrence. When this process is complete, exoskeleton use the information to adapt, learn and optimize their functions. A cognitive process is where an order of tasks including reasoning, planning, and finally the executions [5]. The critical technologies relevant to the new and future progress of an exoskeleton robot involve the interface between human and robot to exchange signal in order to drive an action [6]. A device that converts a physical quantity of measurement into a signal that can be read by an instrument is what we called a sensor.

2.3.1 Joint angle

To map the motion of an exoskeleton robot it requires an accurate and reliable sensors. Encoders are commonly used in wearable robot system. It can be used to measure robot kinematics for teleoperation (Sooyong, et al, 1999), and optical encoders to measure the joint position of exoskeleton robot (Thomas et. al.). Magnetic (hall effect) sensor is used measure position for active joints in biomechatronic hands (Carroza et. al., 2001). The sensors translates rotary motion into electrical signal that have information about the position, speed and acceleration. Although, it shows a good performance to measure joint angle, 3 DOF waist power assistive robot do not perform rotary motion makes the encoder not suitable to be used.

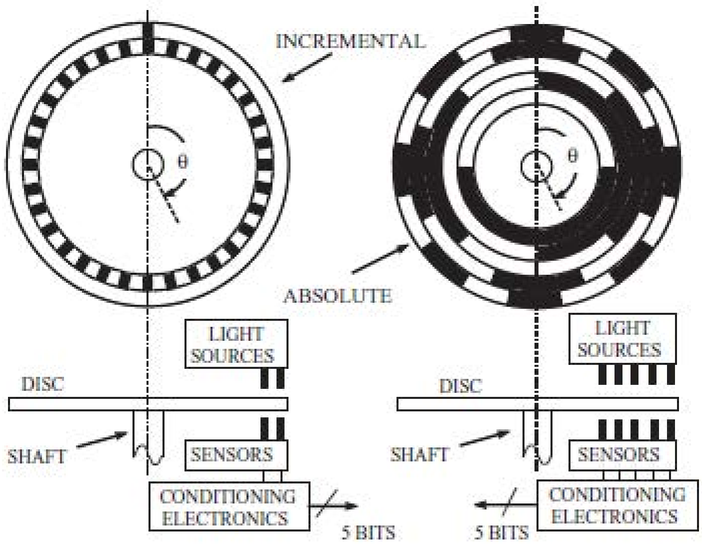

Figure 2.0: Incremental and absolute encoders[7]

Marcos et. al. [8] propose a robust approach for camera and stereo calibration which maps camera coordinates directly into the desired robot frame, using a single LED. The test shows the marker introduce a new robust, accurate and intuitive method for controlling an industrial robot. The system able to perform in real-time. Yet, this kind of mapping method does not suitable to control an exoskeleton robot because the camera only capture the motion, it does not show the angular positon. R. Mendoza et. al [9] used several Inertial Measurement Unit (IMU) on a functional wearable prototype exoskeleton to obtain information of the angular position. Experimental results showed good tracking and regulation behaviour and good fidelity measure was obtained.

Inertial Measurement Unit (IMU) is a microelectromechanical system technology sensor that combines accelerometer and a gyroscope. It is able to measures linear and angular motion.

Figure 2.1: Inertial Measurement Unit [9]

Table 2.0: Comparison between angular sensors.

	Rotary Encoder	Inertial Measurement Unit
Features	-Unlimited range of motion -Digital -Output as data signal	-combination of accelerometer and gyroscope -either digital or analog
Advantages	-Wear free - High precision	-wear free -high precision
Disadvantages	-High cost -Complex to implement	-sensitive to vibration -high cost

2.3.2 Intention detection

There are methods of controlling the exoskeleton via bioelectrical monitoring. It is either using Electroencephalography (EEG) sensor or Electromyography (EMG) sensor. EEG is a method for recording the electrical activity of human brain. The EEG signals can be used to extract the user's attention [10]. Experimental result obtained by Akihiro Yoshino Et. Al (2012) suggest that EEG signals with tested decoding model can be used to continuously decode the elbow joint velocity. However, there are error potential, where it is directly related to the conscious identification of wrong decision by the subject [11]. It can be visualized when the user makes a decision and realizes that it was bad one, even when there is no instantaneous feedback.

EMG sensors are used for monitoring the bioelectrical of muscle activity. The EMG readings can be used to estimate the force during the experiment [12]. According to C. Loconsole Et. Al (2013) the experimental results shows that an optimal force tracking of the interaction force with the object can be achieved.

While it is true EMG sensor shown promising performance, but it is complicated and expensive. On the contrary, Force myography (FMG), the measure of external muscle pressure is, uncomplicated and has reliable way of sensing and giving feedback of muscle activation [13]. During concentric and eccentric contraction of muscles close to the surface, variation in muscle diameter can be notice easily by eye and can be sensed using force transducer such as, force sensing resistor (FSR) [14]. Compared to EMG, FMG is simple to apply and process. Yungher, et al. has experimented the FSR mounted on a cuff to detect pressures in the leg of single female subject.

Figure 2.2: Force sensor resistance [15]

Table 2.1: Comparison between intention detection sensors.

	EMG	Force sensor	EEG
Features	-Measure muscle activity	-Measure force -Measure load distribution	-Measure brain activity
Advantages	-Measure only users intention, contact surface does not affect -Proper interpretation can predict user's intention, reduce delay	-Simple to use -Measure user intention -Low cost	-Extract user intention without moving -Proper interpretation can predict user's intention, reduce delay
Disadvantages	-Requires work on interpretation -High cost	-Noise when contact with different surface -Slight delay	- Requires work on interpretation -High cost -Have high error potential

2.4 Mapping Method

After identifying different feature to assess human intention and joint angle. The next steps includes classification of these characteristic patterns in arrangement to generate the desired output (Arieta et al. 2006). There are several method to map the motion of human body such as Artificial Neural Network and Fuzzy Logic.

2.4.1 Artificial Neural Network (ANNs)

ANNs are one of the best modelling tools motivated from the operation of human nervous system. ANN has multiprocessor computing system, with high degree of interconnection, with simple processing elements (neuron), and simple scalar message carried through the system.

A Neural networks system could be single-layer or multi-layer networks. ANNs could do two main functions; they learn and recall. Connection weights adapt to the knowledge they carry during the learning process. Later, the adapted weights would give a new, and independent output from those of training, input data. There are several learning algorithms like Feed forward back-propagation (BP), The Hopfield rule, The Widrow-Hoff rule, Kohonen self-organizing maps, and Cascade-forward back-propagation (Haykin, 1999). The most widely used learning algorithms is Back-propagation (BP) learning.

2.4.2 Fuzzy Logic (FL)

FL is a concept that often incite first curiosity, then scepticism, has become a buzzword in machine control. It is a method of processing data by allowing partial set membership rather than Boolean membership. This properties make it able to handle noisy, imprecise inputs, and still produce good feedback. Given that the human body is full of signal fuzziness, surface FSR signals could also affected by fuzziness.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Research methodology is said to be the most appropriate way of conducting a research and to determine an effective procedure to achieve the objective. To carry out this study effectively, the methodology involve are designing an experiment, method of data collection, and methods for data analysis.

3.2 Flow Chart

The procedure of this project is portrayed as shown in figure below. The flow chart shows the steps to finish in order for this project to be done. First and foremost, the project's process will be planned. Second, journal of past studies will be analysed to obtain more information that are useful for this project. Next, hardware will be constructed to obtain raw data from the sensors. After that, the output reading of the sensors will be filtered. Following step include the experimentation to determine the position of all the sensors. Next step, is the experiment to map 3 DOF waist power assistive motion using neural network. Before finalizing, the performance of mapping will be analysed. If the performance is poor, mapping