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A Review on Fundamental of EEG for Rehabilitation Robotic Arm

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Abstract: This paper commences on the literature review from various researchers related to my project which is the processing of electroencephalograph (EEG) in detection of muscle fatigue and analyzes processing the data using engineering software. Primary of the research will be explained about fundamental of detection signal from the brain and arms. Second stage is preliminary finding on how to analyze the early stage of muscle fatigue, classification of the human interfacing system and last explanation of Matlab as tool engine of this future research. This research also involve of several robotic arms which is commercially available, however, due to the disadvantage such as weight, expensive and complex mechanism, this research proposed new idea on problem solving by providing a robotic arm which present smart, cosmetic, appearance, practical and user friendly.

Keywords: Review, Rehabilitation, EEG, Robotic, Sensor and Engineering software

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1.0 INTRODUCTION

New technologies have been implemented especially for the interaction with a computer through brain activities. This technology currently available through advanced electronic devices to capture the brain signals and to control the real world devices [1]. There are still constraints and challenges occurred, however brain signals and effective solutions will be upgraded for many of its current research problems. Brain-Computer Interface (BCI) is a complete system including the software and hardware that interpret human signals to control computers and different communication devices. The use of neural signals to directly control a machine via a brain-computer interface (BCI) has been studied since the 1960s [2].

The electroencephalogram (EEG) signal analysis studies are widely used to evaluate neurological disorders such as stroke [3]. Several researchers have used a pattern recognition pattern to classify EEG data into their associated behavioral tasks. However, due to the divergence in number, subject type and analysis processes, pattern recognition methods are not generally evaluated [3]. Stroke damages the tissues of the brain, inducing motor and cognitive impairment. Lost motor functions can be replaced to a certain extent, as neuroplasticity enables undamaged brain tissues to replace the functions of damaged areas [4]. Neuroplasticity is referred as the process of the neurons in the brain reorganizing itself. It is a relearning process that helps the brain to rewire or reorganize itself after an injury. By applying a therapeutic technology along the brain-computer interface, neuroplasticity can be induced in a very short time [5].

2. Type of stroke

Stroke is one of the leading causes of severe disabilities in the developing world. It is a condition when blood flow to the brain is interrupted. Deficiency of blood flow causes the blood to perish. This can cause serious symptoms, lasting disability, and even death [6]. There's more than one kind of stroke. Stroke can be divided into transient ischemic attack (TIA), an ischemic stroke and hemorrhagic stroke [6].

This is stimuli type of stroke spasticity. There is no consensus concerning the number of patients developing spasticity and disability after acute stroke. Although spasticity seems to contribute to disabilities after stroke, spasticity was present in only 19% of the patients investigated 3 months after stroke and increased to 36% after 12 months of stroke [7]. Severe disabilities were

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occurred in almost the same number of non-spastic as spastic patients [7]. These findings indicate that the focus on spasticity in stroke rehabilitation is out of step with its clinical importance. Careful, continual and thorough evaluation to establish the cause of the patient's disabilities is essential before a decision is made on the most proper rehabilitation approach [7]. The aims of the paper is to introduce the type of stroke, anatomy of body and architecture of microcontroller system in order to assist stroke patient during rehabilitation. Thus, the paper review will help other researcher to gain knowledge.

3. Method

Review Anatomy of Arms and Brain

3.1 Brain anatomy

Brain is one of the most complex organs in the human body. It is generally the centre mechanism that controls all functions of the body. Through the five senses of touch, smell, sight, hearing, and taste the brain receives messages, often many at the same time [8]. It does interpret information, regulating our heart and breathing rates, also when it comes to handling the situations. The brain is an organized structure, divided into many components that governed many specific and important functions.

The brain is composed of three parts: cerebrum, cerebellum and brainstem. The cerebrum is the largest part of the brain and is composed of right and left hemispheres. Each hemisphere controls the obverse side of the body. If a brain tumour is located on the left side of the brain, the right arm or leg may be weak or paralyzed [5].

In figure.1 the illustration represent the anatomy of the brain. The cerebrum is divided into four lobes, which are occipital lobe, parietal lobe, frontal lobe and temporal lobe. Once again each lobe may be divided into areas that serve very specific functions. It is important to understand that each lobe of the brain does not function alone. There is a very complex correlation between the lobes of the brain and between the right and left hemispheres.

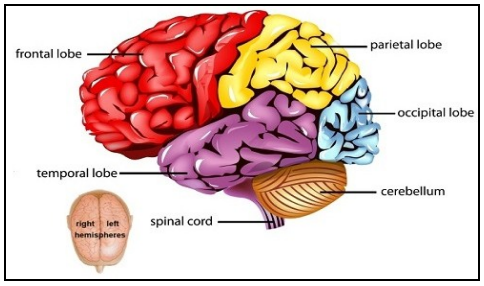

Fig. 1 : Parts of the human brain [5]

Every lobe of the brain has its own functions. The spinal cord is the most eminent structure between the body and the brain. It consists of nerves that carry incoming and outgoing messages between the brain and the rest of the body, making it possible for the brain and body to communicate [5]. It is also the center for reflexes, which acts as an emergency nerves for human reflex when experience the hot, cool and accident. This study focuses on the motion of the Upper Limb, therefore, parts of the brain that will control the arm motion is the motor cortex area. The role of the primary motor cortex is to generate neural impulses that control the transmittal of motion.

3.2 Arms anatomy

The arms and hand are one of the important parts of the human body that performs our daily routine. It is specifically designed to meet the body's diverse needs of strength, speed, and precision while completing many complex tasks [9]. Activities such as lifting weights or heavy boxes require brute strength from the muscles of the arm. Writing, painting, and typing require speed and precision from the same muscles. An athlete such as boxing might require their arm and hand muscles to be strong, fast, and precise all at the same time. Despite an athlete, normal people also utilize their arms and hands in daily lives. In human anatomy, the upper arm is positioned between the shoulder joint and elbow joint [10].

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Figure 2 shows the muscle of the arm. The muscles of the upper arm are responsible for the flexion and extension of the forearm at the elbow joint. Flexion of the forearm is achieved by a group of three muscles – the brachialis, biceps brachia, and brachioradialis. These flexor muscles are all located on the anterior side of the upper arm and extend from the humerus and scapula to the ulna and radius of the forearm [10]. A degree of freedom is a plane of movement. A human arm is considered to have 7 DOF (degree of freedom). Three of these degrees of freedom are at the shoulder, one at the elbow and again three at the wrist. However, it becomes limited somehow for certain stroke patients [9]. While focusing the movement of up and down, parts of upper limb that will be fixated in this research are between the biceps brachia and triceps brachia.

3.3 Process of transmit and receive signal.

Generally, in a normal state, when a person thought to initiate movement, nerve impulses originated in the brain were triggered and then transmitted from brain to muscle cells via neuromuscular junction. Nerve impulses activate the motor unit of the muscle to contract. When this impulse arrives at nerve endings, it stimulates the nerve endings to release chemical substance to make the muscle fibres contract [5]. This impulse can be measured over muscles,

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called electromyogram (EMG). When the brain damage caused by stroke, the regular impulses is not generated, then muscles become weak or paralyzed since none of the signal activates movement. From this long-term immobilization, the muscle will become atrophy, which is no muscle strength [11]. Figure 3 shows the process of transmitting a signal to other neurons.

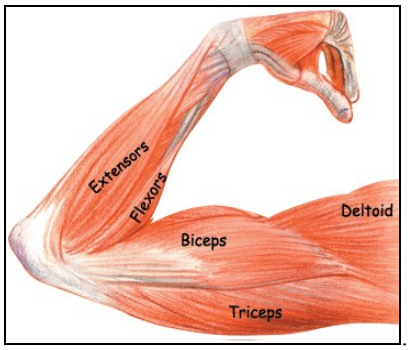


Fig 2 : Muscle of the arm [10]

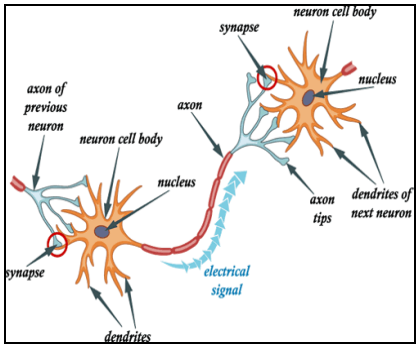


Fig 3: Process of transmitting signal [5].

4.0 Review Process of Rehabilitation on Upper Limb

1) Application of robotic system in rehabilitation technology

Technology of robotics is increasingly demanding in the industry of medical treatment and the humanoid robot. Early 20th century until now various types of robotic were applied to assist the patient. Rehabilitation or medical stroke treatment is one area of growing interest in both research and commercialization. It is very difficult to design robots that accurately meet the criteria and spec of the medical requirements. In fact, many experimental tests of the new algorithm must be done to design a perfect robot. However, the robot only can assists human but not to replace the primary function of human task. Thus, the purpose robot treatment must be friendly, comply with standard medical safety and high technology treatment behind of robotic is very important to introduce.

4.1 Arms robot and force sensor

A human arm typically can feel the sensation. A study has been done by using a sensor that can mapping and calibrated the data measurement of force and torque. The feedback data system somehow could assist to stimulate electrical activity from muscle fatigue on the skeletal muscle to identify what kind of force is applied. To acknowledge the standard force and frequency response from muscle by EMG, the difference activity which is the act of pressure, turning, twisting and tensile played a prominent role in the human body. Based on a different kind of force it can produce a differential response.

The system measure contact-reaction forces and torques at a touch point of a robotic arm using 6DOF measurement devices and data acquisition system [9]. The feedback data of forces and torques is acquired from three Cartesian coordinates (x, y and z).The transducer reacts to applied forces and torques using Newton's third law which stated that, for every action there is always an opposed or equal reaction, or the mutual action of two bodies upon each other are always equal and directed to contrary parts [12]. It is accomplished to evaluate the size, direction and orientation of external force and torque at the specific contact point and then the system manage to follows the human's intention even keeps the robot to be balanced on the different situation and environment. However, the delay still exists and the precision still needs improvement. It is estimated that factors including rotation inertia of the motor and noise of the sensor affected the result. [9] Figure 4 shows that the applied force and torque vector on transducer.

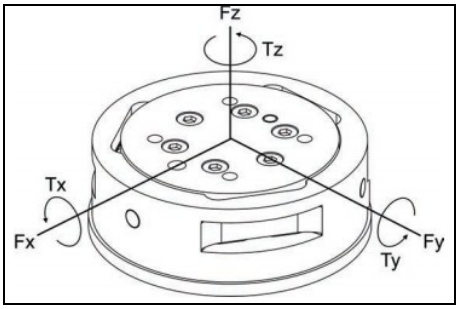


Fig 4: Applied Force and Torque Vector on Transducer. [12]

4.2 Arms robot and EMG

Electromyography (EMG) is a diagnostic procedure to assess the health of muscles and the nerve cells that control them (motor neurons). EMG is one of the

techniques to reveal nerve dysfunction, muscle dysfunction or problems with the nerve-to-muscle signal transmission.

Neurological injuries are the leading cause of disability in the developed world, especially for stroke. The effects of these injuries that include impairments such as muscle fatigue and increased joint spasticity lead to functional inadequacy. Physical and cognitive rehabilitation is typically undertaken to improve impaired motor function resulting from the neurological injury. It has been broadly demonstrated that user's motion intention can be accurately detected by interpreting surface electromyography recordings (sEMG) [13]. Different sEMG-based systems were proposed for the estimation of hand and wrist movements and consequently used as noninvasive interfaces for controlling exoskeleton, prosthetic devices, computer-animated hands in a virtual environment, or for operating robotic arms.

A study is approached on the use of robotic exoskeletons as a supplementary tool for characterizing muscle properties. The musculoskeletal modeling has focused on the development of control strategies for rehabilitative training. A neuro-musculoskeletal model of the elbow, in combination with an upper arm exoskeleton, has been implemented to evaluate neuromuscular characteristics for the biceps and triceps muscle groups [1].

4.3 Arms robot and EOG

The Electrooculography (EOG) techniques allow detecting the movement of the eyes by measuring the potential between the cornea and the retina. In addition, the prevalence of EOG in terms of accuracy and complexity is quite imperative, so it is one of the most commonly used methods to detect eye movement. EOG has been used as an assistive technology in the modern world, specifically for medical purposes. Several works have been done such as for physically impaired users, for example, to control wheelchairs and to control a robot. A study on a processing algorithm for the EOG signals has been developed in order to detect eye movement. Several experiments have been done to test the interface. Six volunteers have been used to control a robot by using the movement of the eyes [14].

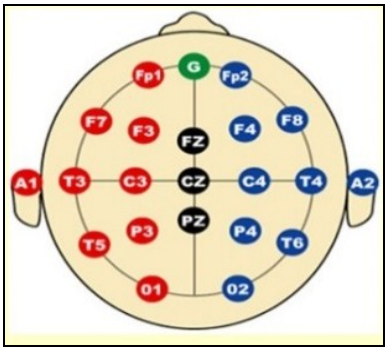
The device with a real robot arm application has been shown that the users are able to perform simple eye movements. Because of its high reliability, the system could be used in different real applications to help people suffering from neurological conditions leading to severe motor disorders.

4.4 Arms robot and EEG

Electroencephalograph (EEG) is the method to signify the signal data information from the brain muscle point. The significant use of EEG is to indicate the brain electrical activity of the human body [11]. The specific muscle point applies to the surface of the head skin is upgrading gradually. The placement is introduced by most research in this area to identifier the high pitch raw data. By assist from the robotic technology, the collecting data of treatment have been applied via the engineering of microcontroller application as mentioned before.

Figure.5 shows the EEG electrode placement on the brain. It is considered as the most significant and reliable physiological signal to indicate mental fatigue. EEG-based technologies allow the real-time characterization of motor-related cortical activities to obtain predictive information regarding intended movements [15]. The signals contain a lot of information related to physiological states.

Recent studies show that there is an interrelation between electroencephalographic signals and position/velocity hand movement parameters [13]. Recent studies observed that uniform and linear movements were better decoded. A passive of robot arms was used to track a circle that moves on the screen [16]. Brain signals are recorded while performing the movements. The accuracy of the data has been analyzed to correlate between the reconstructed and original movements. These findings open new possibilities in upper limb movement decoding, which has already been successfully achieved with intracortical recordings. To decode arm position and velocity, low frequency EEG components are processed and decoded through linear regression models [17]. The patterns were recorded and then analyzed to interpret the signal waves.



Fi. 5: EEG electrode placement

II. Hardware and controller

Microcontroller and processer are vital to interface and mapping the various sensor in different angle of a human body during treatment. In order to comprehend the methodology of measurement collecting data several types of hardware and controller being used to acquire the raw EEG signal. The hardware is related to a circuit and

the design of the prototype as a medium to acquire the signal.

a. Adriano

Adriano microcontroller is the famous controller, because the application of Atmel microchip. The application is easy to interface in any engineering software such as Mat-lab, Lab-view and Visual studio. The microcontroller Adriano also has 12 I/O port and internal 5volt supply and ground. It is a cheap and convenient device for recording and transmitting data through USB cables. It performs reasonably fast analog-to-digital conversion and doubles as a platform for additional circuitry. It's programmed as a serial port but automatically translates to USB. The EEG Data readable by the Adriano amplified the signal using instrumentation amplifiers and operational amplifiers as well as a notch filter and a low-pass filter to make the data readable [2].

b. Pic Microcontroller

A microcontroller is a small computer on a single integrated circuit which designed to control devices. With a program running on PIC microcontroller, a simple motor can be activated using neural signal. A PIC microcontroller is commonly used in an embedded system due to its simplicity and easily operated. It offers several advantages such as design time saving, space saving, and no compatibility problems. However, it has limited memory size and input/output capabilities depending on the type of controller used [16].

III. Review Method of EEG signal processing.

Some artificial intelligence (AI) techniques mainly based on neural networks have been proposed for processing and discriminating EEG signal. Neural network is a computing technique that evolved from mathematical models of neurons and system of neurons. Nowadays, neural networks have become a useful tool for interpretation of multivariate data. There are several methods for processing data such as:

a. Fuzzy logic

The evaluation of EEG signals analysis using several pattern recognition methods comparing analysis to linear and nonlinear pattern recognition for enhanced efficiency of fuzzy logic systems has been carried out. A description of fuzzy logic principles, fuzzy logic systems and brain waves activity analysis within the frame of fuzzy logic methods is also given. Fuzzy logic systems are considered to be an adequate tool for modeling and evaluating cognitive processes and knowledge-based systems. Linear methods like fast Fourier transform (FFT) or wavelet transform (WT) for EEG brain signal waves analysis are used [3].

b. Back Propagation of Neural network

Back propagation is currently the most widely applied neural network architecture. This popularity primarily revolves around the ability of back propagation networks to learn complicated multidimensional mapping. Back propagation methods, was used because of its good performance. There are 196 neurons in the input layer, 25 neurons in hidden layer and one neuron in the output layer of Neural Network structure. Figure 6 shows the Neural Network structure [18]. It has been shown that a neural network classifier can be used to distinguish the features of an EEG by classifying and filtering EEG raw data.

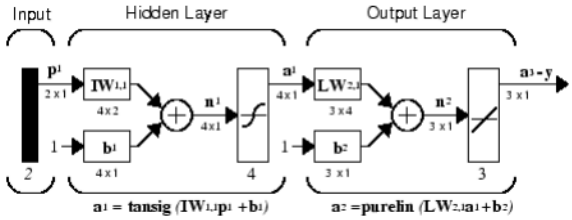


Fig 6: Neural Network Structure [18]

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IV Adaptive Neuro-Fuzzy Inference Systems (ANFIS)

ANFIS is an adaptive network which combines the technique of neural network and fuzzy logic. The characteristics of both of this system not only included, but also eradicate the disadvantages of their oneself-used case. Neural section of the system divided into two learning methods which hybrid learning and back-propagation learning method. The use of ANFIS can make the selection of the rule base more adaptive to the situation [18]. Since ANFIS combines both neural network and fuzzy logic, it is capable of handling complex and nonlinear problems. Even if the targets are not given, ANFIS may reach the optimum result rapidly [18].

5.0 Result and Discussion

Brain control information systems can use different sources of information such as electrooculography (EOG), force sensor, electromyogram (EMG) and electroencephalography (EEG). Among these, EEG signals are particularly relevant, because of their highly accurate temporal resolution and their suitability in clinical environment [19]. EEG-based technologies allow the real-time characterization of motor related cortical activities to obtain predictive information regarding intended movements. Such information has proved to be

valuable in providing feedback at specific moments, which, in turn, induces cortical plasticity and the restoration of the normal motor function [19].

On the other case, the method of processing data resulted that [18] process duration for ANFIS is very short than neural network case. It mentions that ANFIS reaches to the target faster than neural network. When a more sophisticated system with a huge data is imagined, the use of ANFIS instead of neural network would be more useful to overcome faster the complexity of the problem [18]. ANFIS combines the advantages of the neural network and fuzzy logic. An adaptive learning algorithm is applied to the functions to adjust the input-output relationship. It performs the training to define an improved pairing of membership function parameter. Additionally, fuzziness is allowed onto the inputs in order to optimize the outputs provided by nonlinear and non-statistical signals [3].

A data was collected to show that ANFIS gives results with the minimum total error compared to other methods. This shows that the best learning method is ANFIS among the others. However, when the trained parameters were applied to checking data, total error of neural network is smaller than that of ANFIS. Although it looks like a contradiction, the reason of this situation is due to the amount of short data, which is not enough to good learning [18].

6.0 Conclusion

This article represents the foundation and methodological process of Electroencephalograph (EEG) signal interface detection. The fundamental of each part need to be fully understood before implementing the system. There are several techniques that can be used to detect fatigue and to improve the rehabilitation procedure. However, this purpose of study will be focusing on the EEG interfacing system. A successful implementation of this fatigue recognition system will create a tremendous impact on rehabilitation area.

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