Application of EMG and Force Signals of Elbow Joint on Robot-assisted Arm Training

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Abstract

Flexion-extension based on the system's robotic arm has the potential to increase the patient's elbow joint movement. The force sensor and electromyography signals can support the biomechanical system to detect electrical signals generated by the muscles of the biological. The purpose of this study is to implement the design of force sensor and EMG signals application on the elbow flexion motion of the upper arm. In this experiments, the movements of flexion at an angle of 45º, 90º and 135º is applied to identify the relationship between the amplitude of the EMG and force signals on every angle. The contribution of this research is for supporting the development of the Robot-Assisted Arm Training. The correlation between the force signal and the EMG signal from the subject studied in the elbow joint motion tests. The application of sensors tested by an experimental on healthy subjects to simulating arm movement. The experimental results show the relationship between the amplitude of the EMG and force signals on flexion angle of the joint mechanism for monitoring the angular displacement of the robotic arm. Further developments in the design of force sensor and EMG signals are potentially for open the way for the next researches based on the physiological condition of each patient.

Keywords: elbow joint, EMG, force sensor, joint angular, robot-assisted arm training

1. Introduction

The development of robotics and automation technology brings many benefits in many other areas such as biomechanical applications. It used to realize the system of rehabilitation for elderly, injured or handicapped [1-4]. In traditional rehabilitation, require the assistance of a therapist with limited by the ability and time. Several biomechanical systems [5-7] has been designed to overcome these limitations. Robotic arm with joint angles supported for the rehabilitation of elbow movement. Because the upper arm engaging in human activities, flexion-extension based on the system's robotic arm has the potential for a patient to an increase in the movement of the elbow joint. To be suitable for rehabilitation, muscle activity monitor patients should be observed for the joint motion for adjustment of arm strength between the patient and the robotic arm.

The force sensor has been used in robotic exoskeleton [8, 9], where it was detected and indicating the torque applied to the joints of the robot. Recent research in the application of the force sensor or load cell sensor for trajectory control arm [10, 11]. Haptic force control can be used in robotic rehabilitation training to help and improve the mobility of the arm of the patient [12, 13]. The armed force is generated from the torque between the robot grip and the user's hand as an input signal. This signal is used to control the robot to monitor the burden on muscle activity of the user.

EMG signal support biomechanical system to detect electrical signals generated by the muscles of biological containing information about the condition of the muscles. The signal can represent the condition of the human hand gestures. Researchers have explored the characteristics of the EMG signal on a human arm muscles to predict the elbow joint angle [14]. In a previous study [15], the proposed control robotic arms using signals EMG and PID control in order to initiate movement before the movement of patients assisted in providing therapy. EMG signals from the robotic exoskeleton has been implemented to control the impedance to generate a movement that has been determined for the user [16].

The robot-assisted arm training is used to control the angle of the joint for biomechanical devices that require the signal correlation between EMG and force signals [17]. Here, the purpose of this study was to implement the design of force sensor and EMG signals that are prospective to improving performance by increasing the robot arm moves to control the angular displacement. In this paper presents a designed of the force sensor and used of the EMG signals for one degree of freedom robotic arm. The elbow flexion motion of the upper arm at an angle of 45º, 90º and 135º was implemented on the healthy subject. The signals from the biceps and force sensor signals presented signals monitored correlations between muscle strength and joint motion to compare responses from joint angles. The correlation analysis exerted from the experiments was studied with the purpose of monitoring the upper arm movement in the vertical plane to apply on the robotic arm.

2. Method
2.1. Materials
Previous research explains that the joint motion based rehabilitation is capable of operating to monitor the movement is capable of controlling the prototype robot arm [18]. The material in this paper, the mechanical arm consists of one degree of freedom exoskeleton to assist movement of the wrist joint is shown in Figure 1. The movement of the upper arm and forearm using a DC motor. To measure the angle of the joint using a potentiometer. To measure the force between the user and the robot, the modified force sensor arranged in the forearm. Load cells used in the detection of the signal strength generated during the user's arm moved. If the force applied to the upper arm joints and produce the same joint torque, it will create the same joint movement [19, 20]. In the next section, EMG signal as a measure of muscle activity is presented. The block diagram of the output signal of the human elbow joint movement is shown in Figure 2.
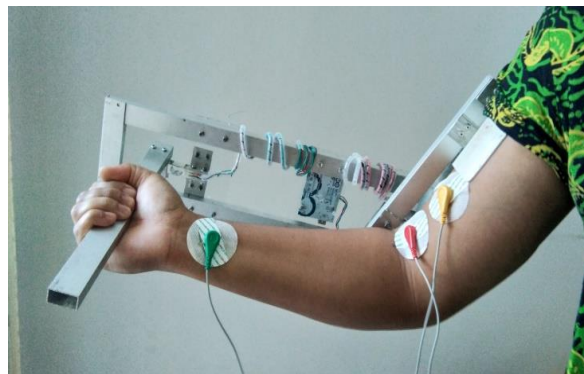

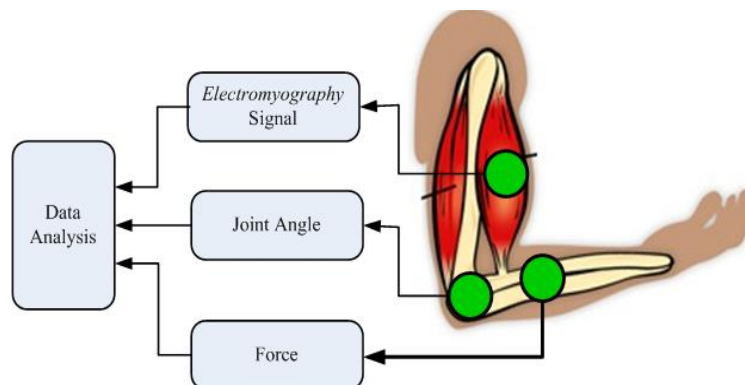Figure 1. The prototype of robot-assisted arm training

Figure 2. Block diagram the outputs signal from the human elbow joint

This success to identify the signals performed in the experimental tests is highly dependent on the physiological conditions of the subject. The subject must be accustomed to the mass of mechanic hardware and torque-free motion that prevent successful simulation. During the electrode placement, it makes a wide range of frequencies containing the EMG signal. Raw EMG signals to be extracted, for this study used a normalization of EMG signal strength of the signal.

2.2. Experimental Setup

In experimental settings as shown in Figure 3, the system uses a load cell for monitoring the power of the robot in motion in the joints. Potentiometer with an analogue voltage, allowing the resistance value changes with the angle between the joints to represent degrees of an angle measured. The microcontroller unit in this work uses the Arduino UNO module which serves to capture the signal of force and the angle of the joint.
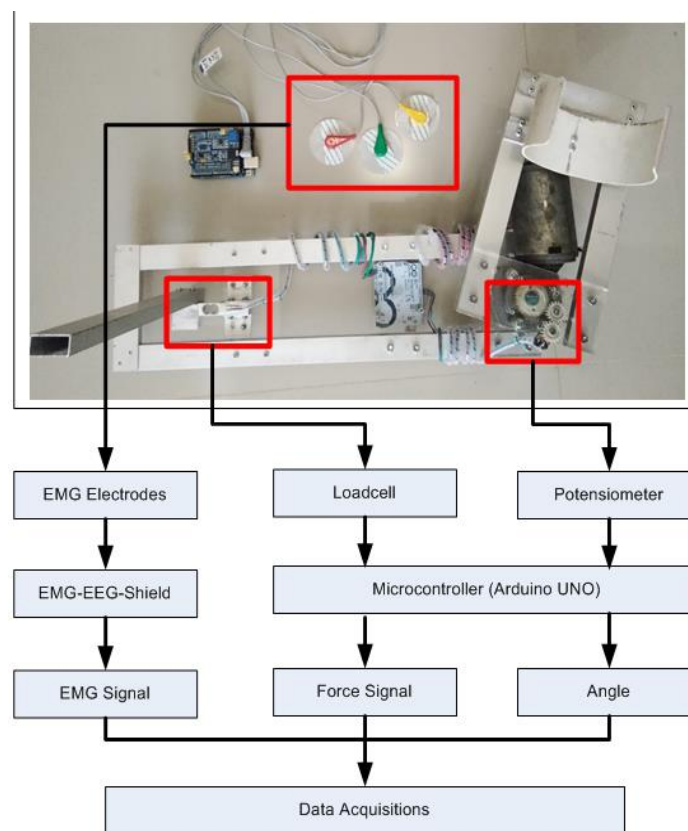

Figure 3. The experiment setup

The collection and recording of electromyography data are performed using SHIELD-EKG-EMG extension module. Intake of signals by placing disposable electrodes on the elbow muscles (biceps) of the subject. The subject in a sitting position during the experiments were conducted. After laying the electrode, the arm moves with the movements of flexion at an angle of 45º, 90º and 135º that aims to identify each measurement signal based on the amplitude. Normalization is used in the extraction process the EMG signal has been obtained, after signals are measured and stored in a computer unit. To extract a signal, in this paper has been calculated for this study used a normalized value of the raw EMG signal.

The experimental setup is at the Airlangga University Laboratory of Electronics and Instrumentation with the included test equipment. In the simulation based arm rehabilitation arm, elbow joint movements performed in healthy subjects. The subject sits on the chair and the arm

wearing the mechanical arm. Subjects have trained some movement experiments. Movement between the positions of the arm elbow is in a relaxed position until the arm is fully flexed.

3. Results and Discussion
3.1. Simulation and Output Data Processing

In this experiment, focusing on extract information about the raw EMG signals from the human upper arm. The EMG signal has been collected using SHIELD-EKG-EMG with a surface electrode on the skin above the upper arm muscle. Subjects perform a repetitive arm motion with the elbow at 45º, 90º and 135º at a constant speed.

In tests, the potentiometer rotates during the movement between the upper arm and forearm rotates in the vertical plane to monitor the position of the robot arm joints. Potentiometer is attached to the motor shaft connection and provide information of value angle. In the arrangement for angular position sensing using a 50-ohm linear potentiometer. The reference position is the actual angle of the mechanism of the robot arm system.

The accuracy of the angle sensor is tested by using a goniometer into the joint and is read simultaneously between the angular value of the goniometer and the angle sensor. To show the test results in flexion between the upper arm and forearm, the test was changed from 40° to 140° with steps every five degrees. This comparison is done in healthy subjects the 27-year-old man three times.

To perform the task for the robot arm using a potentiometer, the robot moves to a certain position and then record the position of the joint angle. Movement of the joint to the counterclockwise and clockwise position for a single movement. The addition of five degrees each movement is used in every corner to monitor the move at any angle. Monitoring goniometer position in the vertical plane has been calculated using a kinematic model of reading and reference sensor as shown in Figure 4.
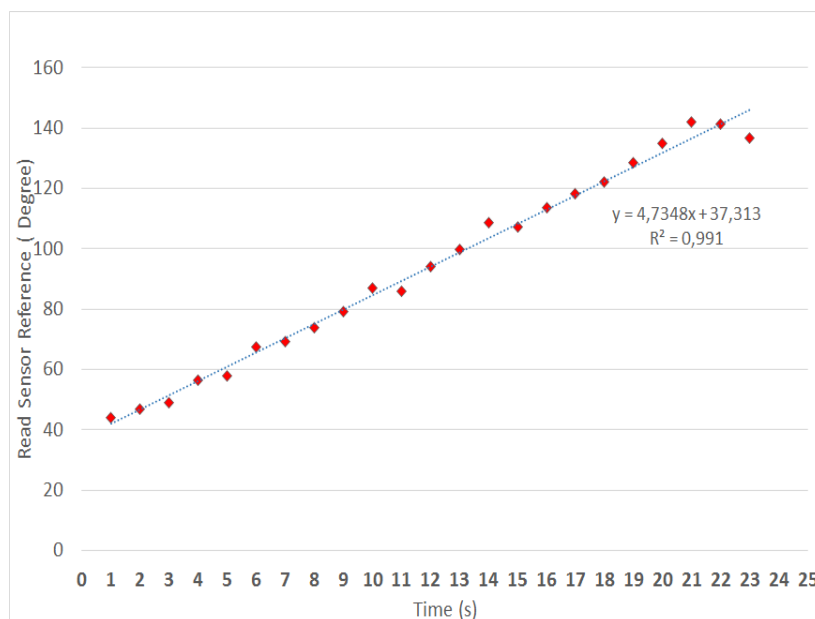

Figure 4. Position monitoring of the angle joints

The comparison between the position and angle sensing angle actually has a sensitivity is 4.73 ˚ and the average error of measurements is 0.69˚. Results showed potentiometer has good accuracy in measuring the angle of the joint with a correlation of 0.99. Performance force sensor is verified by measuring the voltage value of maintaining muscle flexion isometric arm in terms of muscle stiffness. Tests have been conducted with healthy subjects who were able to perform the movement without support. In this experiment performed to demonstrate human

hand muscle strength in static movement between the actuator torque robotic arm systems. Load cell as a force sensor mounted on the handle of the robot arm to measure the target are the biceps muscle. The observed force results during the fully flexed arm in the vertical plane is shown in Figure 5.
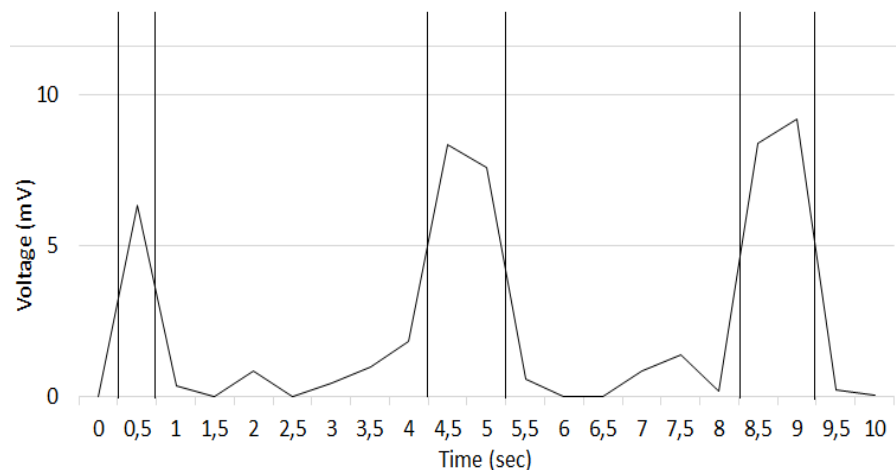

Figure 5. Changes signal measured according muscle contraction

Experiments show that the relationship between the voltage value and flexed arm associated with the force acting on the subject of the wrist joint. The voltage change of the force sensor during movement flexion over time during the elbow joint moves. The response time of the sensor is tested against the joint forces on the sensor to measure the ability of muscle activation.

The robotic arms are designed to have one degree of freedom can be spun from 40 to 140 degrees with the angular velocity is 10 degrees/second constant. The microcontroller unit is used to command and control a DC motor speed. The experiments in this research were conducted with the healthy human. After the experiment, the force sensor monitors the muscle strength described as shown in Figure 5. If the force applied to the arm joints on the robot arm, it produces the same joint torque and the results of the same movement of the arm joints.

In experiments with the same angular velocity, testing is done on a human arm flexion movement of external forces applied to the robot mechanics. Amplifier module HX711 is used for low voltage output signal from the force sensor. Force sensors are used to detect the physical strength to support the robot to monitor the human arm muscle strength to move in accordance with a predetermined movement. Measured external impact force indicated by the signal voltage increases.

Peripheral devices to record the raw EMG signal using 10-bit ADC with a sampling rate of 256 Hz and has been built with a Bessel filter third order, cutoff frequency at 40 Hz. The simulation results from the motion of the elbow joint showing raw recorded every two seconds. Having obtained some segmented signals with 2000 iterations in each experiment for one cycle of flexion movement generates for this study used normalized value for a single joint movement is simulated.

By giving flexion of 45° provides a small amplitude signal with increased amplitude with minimum ADC value of 237 and a maximum of 302. In other circumstances when flexion 90° carried in one second, 200 the sampling data are acquired. In other conditions when the 90° flexion movement is performed in 1 second, 200 samples of the sampling amplitude of the signal tend to have an amplitude increase between 207 and 379. In Figure 6 is shown EMG signals to flexion at 135° can be clearly distinguishable because it has a high amplitude 99 to 345. From the graph, it can be observed changes in the amplitude increase, this means that the relationship between the angles of flexion is proportional to muscle activity signal value.
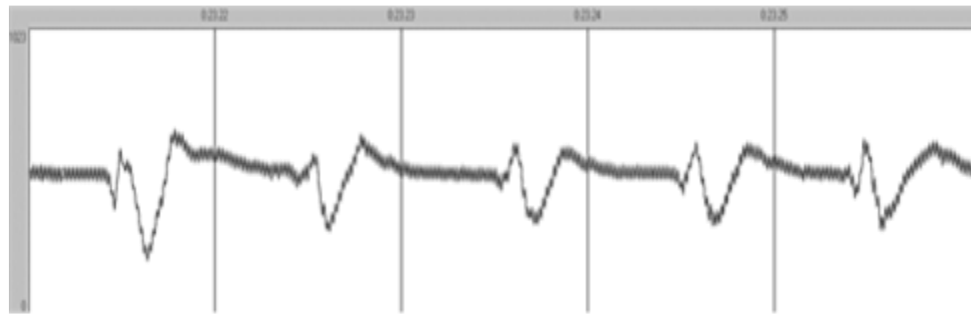
(a)
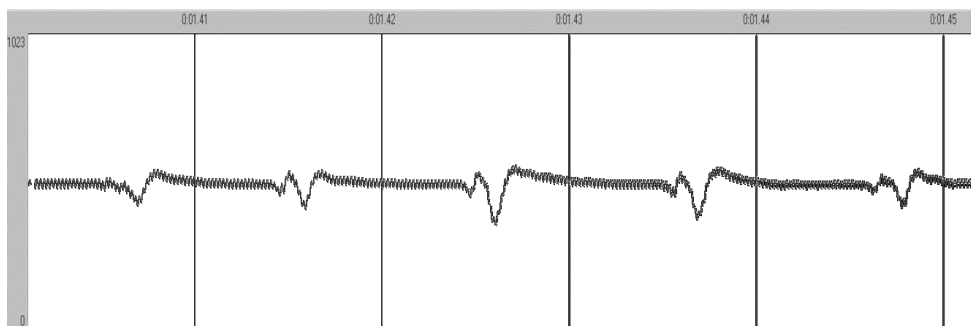
(b)
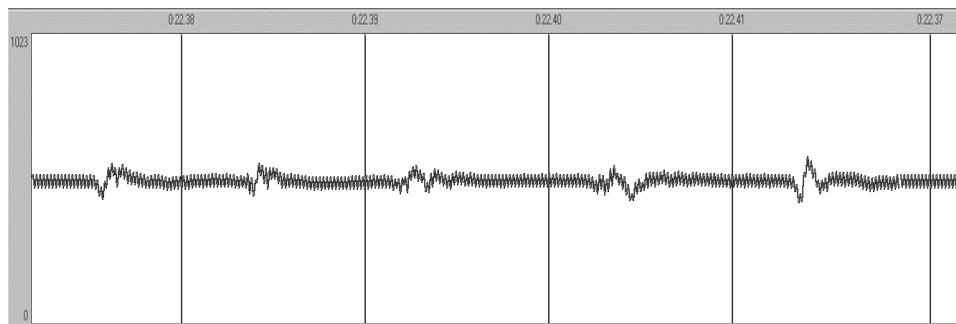
(c)

Figure 6. Raw EMG Signal Simultaneous Movements of Elbow
Raw EMG signal with elbow joint angle at (a) 135º (b) 90º (c) 45º

3.2. EMG Signals with Normalized Values

Based on the experimental in this study, we got the raw EMG Signals to measure the electrical activity of muscles in the arm. Tests carried out by three movements in the elbow joint, flexion at position 45°, 90° and 135°. This movement will result in EMG signal that is the raw signal and the graphical user interface is used to display the signal. When the arm moves, muscle activity to be recorded, the recording of this signal will be displayed in the form of a signal in the time domain. Measurement signals from electrodes that have been applied to the skin, the results showed that EMG signals have properties that can be differentiated, so that the signal analysis using the amplitude value is a method that may be used.

The raw data that has been obtained then do the normalization process that is performing calculations on rows of data normalization. This process is used to make the data more easily observed because of the difference between flexion moving at a low angle value has a value that is less clear [11]. Figure 7 shows three images from the normalized signals as arm muscle contraction. The maximum amplitude value that is obtained through normalization
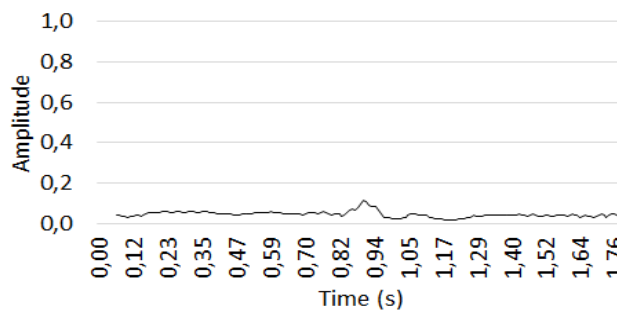
signal when the movement of the arm 135° is 1.79, when the arm is raised at 90° maximum voltage of 0.24 and for movement at 45° worth 0.17.
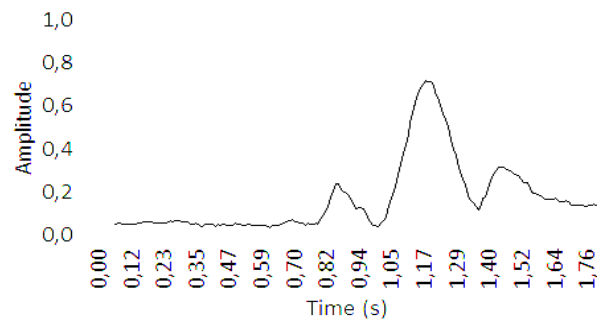
(a)
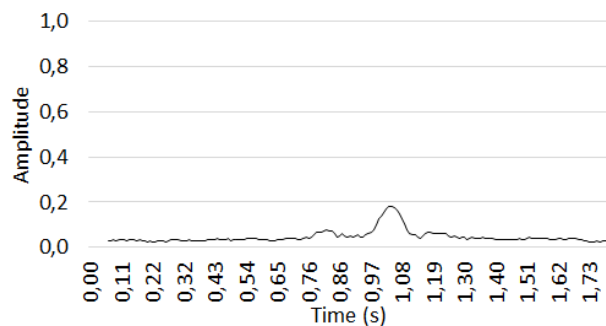
(b)

(c)

Figure 7. Normalization of EMG signals
normalization signal with elbow joint angle at (a) 135º (b) 90º (c) 45º

4. Conclusion

Robot-assisted arm training to help the human elbow joint motion was evaluated by simulation. Force sensors and EMG signals have been applied to monitor the electrical activity that occurs in the arm by the elbow joint movement. Experimental evaluated in future studies to single joints to aid movement of the elbow joint. The results showed EMG signals from relationship information flexion at an angle at 45º, 90º and 135º with normalized values. The experimental results confirm that using force sensors and EMG signals will be able to provide the information on muscle activity that applied to the robot arm rehabilitation. Future work will include the development of control systems using EMG and force sensor signal to control the angle of the arm that can adjust to the natural movement of the human arm.

Acknowledgements

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