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Flex Sensor based Biofeedback Monitoring for Post-Stroke Fingers Myopathy Patients

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Abstract. Hands are one of the crucial parts of the human body in carrying out daily activities. Accidents on the hands decreasing in motor skills of the hand so that therapy is necessary to restore motor function of the hand. In addition to accidents, hand disabilities can be caused by certain diseases, e.g. stroke. Stroke is a partial destruction of the brain. It occurs if the arteries that drain blood to the brain are blocked, or if torn or leak. The purpose of this study to make biofeedback monitoring equipment for post-stroke hands myopathy patients. Biofeedback is an alternative method of treatment that involves measuring body functions measured subjects such as skin temperature, sweat activity, blood pressure, heart rate and hand paralysis due to stroke. In this study, the sensor used for biofeedback monitoring tool is flex sensor. Flex sensor is a passive resistive device that changes its resistance as the sensor is bent. Flex sensor converts the magnitude of the bend into electrical resistance, the greater the bend the greater the resistance value. The monitoring used in this biofeedback monitoring tool uses Graphical User Interface (GUI) in C# programming language. The motivation of the study is to monitor and record the progressive improvement of the hand therapy. Patients who experienced post-stroke can see the therapy progress quantitatively.

1. Introduction
Hands are one of the crucial parts of the human body in carrying out daily activities. However, hand injuries or hand accidents are the most common. As a result of this accident is a decrease in motor skills of the hand so that therapy is needed to restore motor function of the hand on a person. In addition to accidents, hand disabilities can be caused by certain diseases, one of which is a stroke. Stroke was the second leading cause of death after heart disease. Based on WHO data in 2012 there were 6.7 million people worldwide suffering from stroke [1]. Biofeedback is an alternative method of treatment that involves measuring body function measured subjects such as skin temperature, sweat activity, blood pressure, heart rate and hand paralysis due to stroke [2]. To date existed biofeedback-based monitoring system use sensors such as electromyograph (EMG), electrodemograph (EDG),

electroencephalograph (EEG) and electrocardiogram (ECG). In hand therapy-based mechatronic systems, EMG sensors are widely used in decades due to its capability for measuring the muscle strength [3]. In addition to the muscle strength measurement, another indicator that showing the improvement of hand therapy program is necessary.

This indicator is the angle of finger motion. By monitoring the angle of finger motion and showing the result to the post-stroke patients, it will stimulate the patient's motivation for doing regular therapy. This idea is the main contribution of this paper. According to the capability of flex sensor that reported in the latest research papers [4, 5], we select flex sensor to measure and to monitor the angle of finger motion of myopathy patients. Flex sensor is a mechanical sensor where it works is to change the value of resistance when the sensor is curved. Flex sensor is designed with some resistive material so it can produce the resistance [3]. Biofeedback with flex sensor aims to monitor hand rehabilitation therapy of patients who are paralyzed due to stroke. This paper present preliminary study in developing a biofeedback-based monitoring system using Arduino and C# programming language. The C# programming language is a tool of programming (Rapid Application tool) created by Microsoft Corporation and can be used to create Grades-based programming using a C++-like programming language [4].

2. System

2.1. Wiring diagram of electronic parts and circuit

Wiring diagram is a visual representation of the connections and layout of electrical parts and systems. Wiring diagram show how the electrical components and cables are connected to build a system to assist the manufacturing process. In this paper, fritzing software was used to show the wiring diagram as presented in figure 1. This software can also display schematics for print circuit boards (PCB) and assist PCB manufacturing process. The schematic circuit diagram is presented in figure 2.

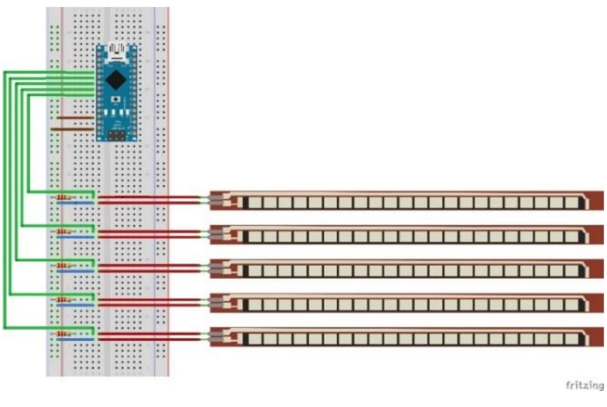

Figure 1. Wiring diagram of biofeedback system.

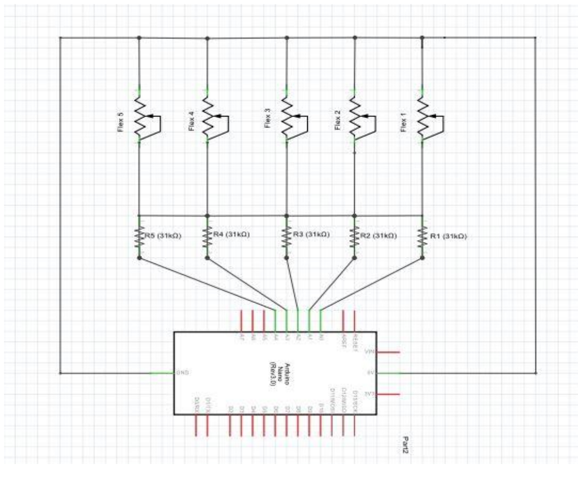

Figure 2. Schematic circuit diagram.

Table 1. Analog input configuration.

Analog input code	Description of fingers
A0	Thumb
A1	Index
A2	Middle
A3	Ring
A4	Little

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2.2. Flex sensor attachment on the glove

Each flex sensor has a different resistance value. The resistance value increase proportionally to the bending angle of the flex sensor. Therefore, the flex sensor must be placed in a mixed condition instead of in a free movement. In this study, the flex sensor is attached on the glove with sewing method and glue as shown in figure 3. Sensors that have been placed on the gloves then read the size of the resulting resistance by means of integrating with microcontroller. Microcontroller used is Arduino Nano V3.0 ATM328 because compared with other Arduino, Arduino Nano type have smaller size than others, so can be more portable. Flex sensor has two cable connection parts, positive and negative. These are connected to PCB. The glove, Arduino and PCB connection of biofeedback monitoring tool can be seen in figure 4.

Figure 3. Glove with flex sensors.

Figure 4. Glove, PCB and Arduino installation.

2.3. Flex sensor calibration

Flex sensor calibration is done by reading the ADC value generated when the sensor is in normal and bent condition. The purpose of this calibration is to align flex sensor motion with appropriate angular output results. Flex sensor calibration with gloves can be done by making the angle on the paper depicted by the measured lines of the angle by using the arc ruler shown in Fig. 5. Then the resultant angle that comes out on the arduino is equal to the angle measurement with the arc ruler.

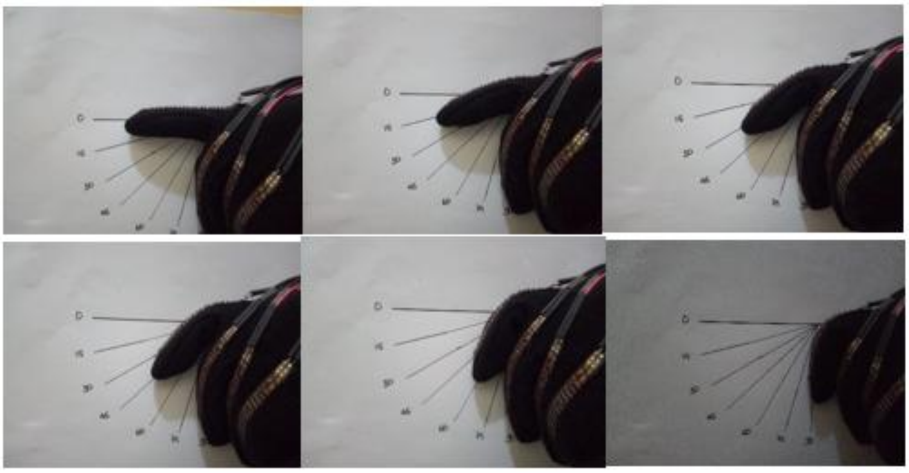

Figure 5. Manually-calibrated angle.

Arduino has an analog pin connected to a converter known as analog-to-digital converter (abbreviated ADC or A/D). This converter converts the analogue value of a Voltage signal into a digital form so that these analog values can be used more easily and applicable. In Arduino, this converter has a 10-bit resolution, meaning the conversion value ranges from 0 to 1023. At a voltage of 5 Volts (maximum), the Arduino will read a value of 1023, and when the voltage is 0 Volt (minimum), the read value is 0.

After the flex sensor can adapt to get the maximum and minimum values, the value is mapped to a value of 0-180. The resistance change can be measured through Arduino programming (analog pin reading) by putting a 31 kOhm resistor, which serves as a voltage divider that divides the 5 Volt voltage between the flex sensor and the resistor. By placing a 31 kOhm resistor, we will find an equation related to the resistance (partly due to flex) of the flex sensor to the voltage reading through which it passes. This resistance will be obtained by using a voltage divider as shown in quation (1).

$$V_{out} = \frac{legible\,value}{1023} x5volt \tag{1}$$

where V_{out} is flex output voltage

The V_{out} value is obtained from the value shown on the Arduino serial monitor showing the voltage value of the analog input port. Since Arduino uses 10 bit analog inputs then to find the value of V_{out} using equation (2).

$$V_{out} = V_{in} \frac{R_2}{R_1 + R_2} \tag{2}$$

where V_{in} is an Arduino input voltage (volt), R_1 is flex sensor resistance (kOhm) and R_2 is resistor resistance (kOhm).

3. Results

Graphical User Interface (GUI) is an interface on an operating system that uses a graphical display, can be controlled using a variety of input devices, such as sensors. The GUI used for biofeedback monitoring uses Microsoft Visual Studio 2015 with the C# programming language (C sharp). The GUI made with C# programming language can be seen in figure 6. The generated GUI from the toolbox used is presented in figure 7 when the flex sensor gloves are paired on the fingers of the integrated Arduino Nano v3.0 Atm328 microcontroller.

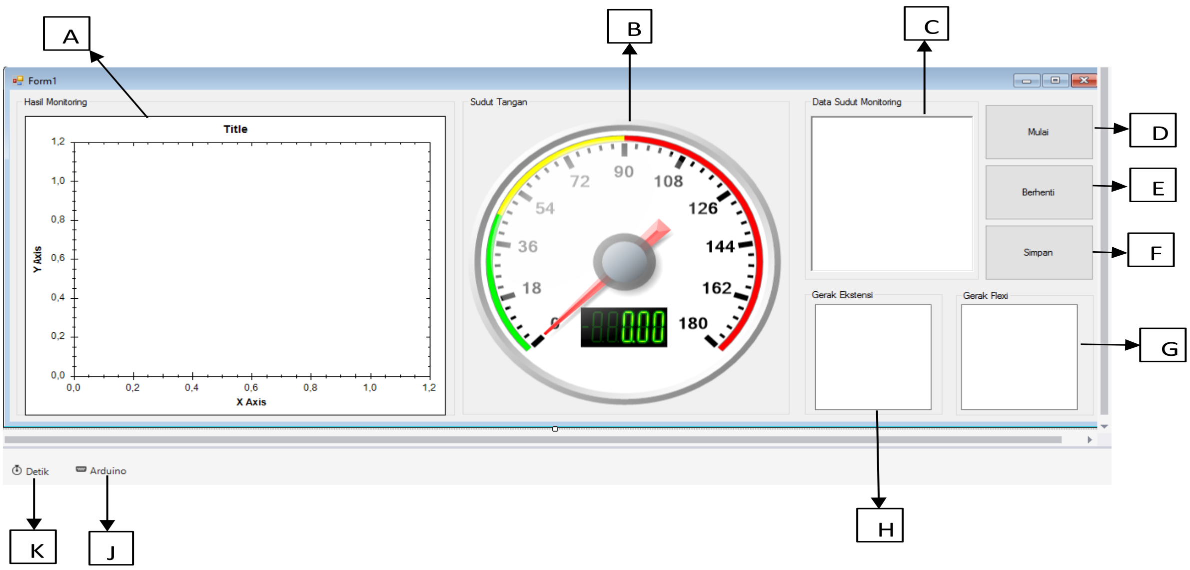

Figure 6. Biofeedback monitoring GUI.

Table 2. A description of biofeedback graphical user interface (GUI).

Code	Type of function on GUI	The purpose of the GUI function
A	Zedgraph	To create real-time degree monitoring of the fingers being monitored
B	Angular Gauge	To display angle animation in real-time
C	Richtextbox	To display the angle number of the finger being monitored
D	Start button	To start the monitoring process
E	Stop button	To stop the monitoring process
F	Save button	To store monitoring results in richtextbox
G	Textbox (extension motion)	For extension motion measurement of biofeedback monitoring user
H	Textbox (flexion motion)	For measurement of flexion motion user biofeedback monitoring
I	Digital monitoring	To display measurement result digitally
J	Arduino serial port	To create a relationship between Arduino IDE with C # programming language
K	Timer (second)	To enable the program operate in real-time

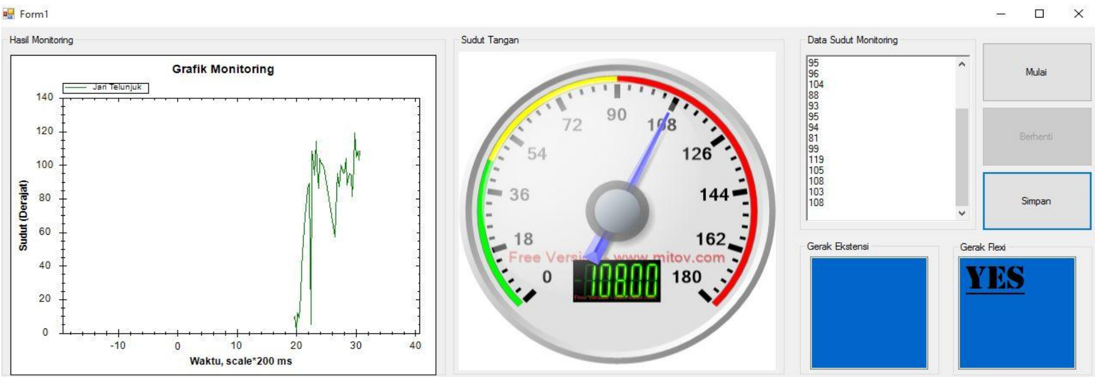

Figure 7. GUI display during the monitoring.

A biofeedback equipment that can be used and can be integrated with a GUI created in Microsoft Visual Studio 2015 with the C # programming language, here are the steps of measuring radius with a biofeedback equipment:

1. Hand to be measured, inserted into a glove that has been installed flex sensor as in figure 8.
2. Connect the integrated flex sensor gloves in the GUI in C # programming.
3. Start monitoring by looking at its interface on the GUI.
4. The monitoring results show that the extension box will be "Yes" when the angle is less than10^{o}, while the flexion box field will "Yes" when greater than 10^{o}.
5. After the results of monitoring finger measurements have been obtained, then the results of monitoring angles can be stored in the form .xls file. And can be opened in Microsoft Office Excel.

Figure 8. Before putting on biofeedback gloves and after wearing biofeedback gloves hand.

4. Conclusions

The biofeedback monitoring equipment successfully integrated with the flex sensor for flexion movement and finger extension, the equipment also managed to monitor the fingers, and can do the measurement for the motion of extension and flexion. The future works of present study is validate and test the biofeedback system to the myopathy patients in dr. Kariadi General Hospital, Semarang, Indonesia.

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