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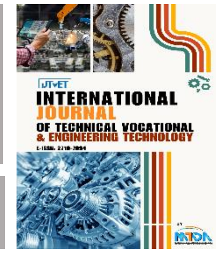

Shoulder Physio Monitoring Device Using ESP32 Microcontroller and Web Applications

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ABSTRACT

Physiotherapy is the process of monitoring and treatment applied directly to the physical body, usually involving injury such as in physical muscle by methods such as massage, heat treatment, and exercise rather than by drugs or surgery. Most physiotherapists, use the traditional method by relying on impairment measures such as range of motion and muscle strength and closely monitoring continuously on the patient progress. This traditional method may affect the standardized measures thus implying the effectiveness of the physiotherapy process itself. Therefore, it will impact the patient's healing process due to incorrect exercise. For that reason, the objective of this project is to help the user who has a shoulder problem to be able to monitor their shoulder angle movement while doing the physiotherapy process. This system consists of a microcontroller ESP32 as the main controller to process the signal input/output and as a communication device to connect with Wi-Fi adaptor, a flex sensor to measure the angle of the shoulder movement in one abduction axis. The OLED are used to display the desired angle movement and the buzzer only give the alert sound when the angle is reach at 90°. This system communicates with the Web Applications to display the real-time shoulder angle position and also can act as secondary monitoring for the user or physiotherapist who treats them. The circuit has been designed with the smallest possible size to ensure the user is comfortable with the prototype. This prototype has been successfully tested and can be one of the effective methods to aid people with shoulder posture-related problems.

1.0. Introduction

Shoulder is one of the most vital parts in human body and located at upper limb of the body. The shoulder joint is a ball joint and socket joint with the Glenoid Cavity, the lateral part of the scapular bone (shoulder blade). This shallow Glenoid Cavity allows the shoulder joint to have a large range of motion (McLaren, 2022). This structure is also a weakness of stability where these joints are at risk of dislocation caused by extreme sports injuries or falls. When the base of the Humerus bone comes out of its normal position, the shoulder is said to have dislocated. If the base of the Humerus bone does not come out completely, but only half, it is said to be subluxation. According to Abrams & Akbarnia (2022), there are two main types of shoulder joint dislocations:

i. Anterior Dislocation: The base of the humerus bone comes out of its location, towards dislocation is the most common and frequent injury experienced

ii. Posterior Dislocation: The head of the humerus moves out of its location, towards the back.

Shoulder pain or problem can be caused by the joint itself or any muscles, ligaments or cartilage near the shoulder normal joints will worsen in performing activities or movements with hands or shoulders.

The method to treat the shoulder injury is through physiotherapy. Physiotherapy is a process of monitoring and treatment applied directly to physical body. Most physiotherapists, using traditionally method by relying on impairment measures such as range of motion (e.g., angle) and muscle strength and closely monitoring continuously on patient progress (D. Abrams et al., 2006). The manual technique of physiotherapy comprises of soft tissue, joint mobilization or manipulation techniques (Kromer, 2014). In order to treat the shoulder problem, one of the methods is to do regularly physiotherapy process, and the process must be continuously and reach certain target (degree movement). Some exercise requires certain angle to complete the physio treatment.

Certain physiotherapy exercise follows the standard operation procedure according to certain practice. (e.g., shoulder flexion angle measurement, abduction measurement etc.). In order to achieve this, the patient or physiotherapist must measure the angle movement by using certain tools or instrument, manually, the angle can be measure by using goniometer. This project is intentionally to build the angle measurement device when the exercise is carried out. The sensor is use to get the signal and calculate the angle based on the movement of the shoulder. By the development of the project, it can help the patient and also the physiotherapist to do right movement according to the angle itself. Any mistreatment can be avoided (example, over angle when do some exercise) and hopefully it can help the patient to recover faster than expected.

1.1. Problem statements

It is common for the patients with shoulder pain to often see a doctor for an examination of the patient's shoulder and took a relatively long time. Besides that, the patient who do the self-physiotherapy cannot determine the accurate angle while do the exercise. They need help from someone else to measure the angle of the movement. example physiotherapist, nurse, or second person (siblings, etc.). Manually reading always lead to inaccurate due to human error.

1.2. Scope of project

Scope of this project only focused on the shoulder part. For the angle measurement, it only reaches at the maximum degrees of movement is 90º. This project is limited for the one axis shoulder movement.

1.3. Project objectives

The objectives of this project are:

i. To develop prototype for shoulder monitoring movements using flex sensor.

ii. To develop web monitoring to monitor angle changing.

iii. To develop integrated system between ESP32 and web application for shoulder monitoring.

2.0. Literature review

Some studies have been conducted to discover the suitable design to develop this shoulder posture monitoring system. One of the studies had been done is from Radzi Ambar and his team 2011 for arm rehabilitation assistive device. These systems maybe involve attaching devices to the affected human limbs in order to monitor patient's movement in any environment of rehabilitation. The author aims to produce a rehabilitation system which is able to assist the rehabilitation of post-stroke patients and gaining quantified results by portable data logging capabilities may enable clinician to do remote monitoring and provide organized sets of data on daily basis every time the user doing the rehabilitation workout at home. The development of the device consists of software and hardware development. The hardware developed consists of two parts, main unit and sensory unit. The main unit consists of an Arduino Duemilanove microcontroller (5V supply), a tactile push button and a 16x2 RT1602C Liquid Crystal Display (LCD).

Arduino Duemilanove microcontroller has been used in this device to process and control signals generated from the sensors. LCD display and the push button are connected to Arduino's input and output (I/O) ports. The LCD will provide the user with readings from the sensor. The main functions of the main unit are to receive command signals from the computer and translate it into control signals, as well as to process the raw data collected from all sensors from the sensory unit and sending them back to computer. Another study has also been conducted by Saggio, 2016 in order to use the proper sensor based on flex sensor comparison. The selection of the flex sensor is suitable to measure the degree bending or flexing with relatively easy and a very low budget. The flex sensor is lightness, compactness, robustness, measurement effectiveness and low power consumption make these sensors useful for manifold applications especially in this fields. Another system has been studied is developed by Abdullah Beyaz, 2017, this system using Arduino Uno, flex, Bluetooth and a buzzer to monitor the posture of farmer arm and leg while they are doing their work, the purpose of the system is for a safety tracking with an audible warning support developed for any threshold value, that selected during a posture angle measure of agricultural work. The system is using Bluetooth as the communication tools to communicate with smartphone for monitoring purpose. These studies can be summarized as table below.

Table 1: Analysis and comparison of the research

No.	Research/Project Title	Strength	Weakness
1	R. Ambar (2011), Arduino Based Arm Rehabilitation Assistive Device	Can be apply in x-y-z axis with IMU sensors attached	Bulk in size, overall design cannot install directly into the user
2	G. Saggio (2016), Resistive flex sensors: a survey	Wide usability of a flex sensor in multi-area of research	Change the property of the electric signal due to repeated bending (material stress)
3	A.Beyaz (2017), Posture determination by using flex sensor and image analysis technique	Using less sensor in experimental setup	Complex system and less accurate due to high increment, cannot communicate long distance due to short distance Bluetooth range

3.0. Methodology and System Design

This monitoring system is divided by two parts which are hardware, consist of the input, output and microcontroller part. Other part is the software consists of Arduino IDE to program the ESP32 and Web applications to display and monitor the user's shoulder movements. The complete system proposed is shown in Figure 1 and Figure 2.

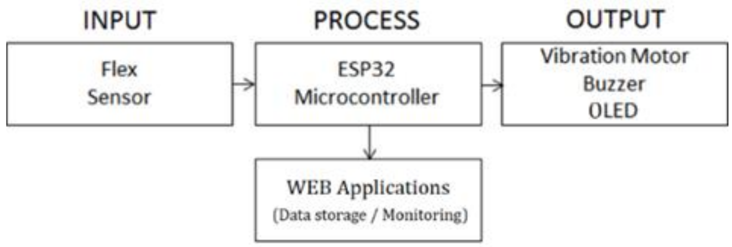

Figure 1: Shoulder posture monitoring system proposed

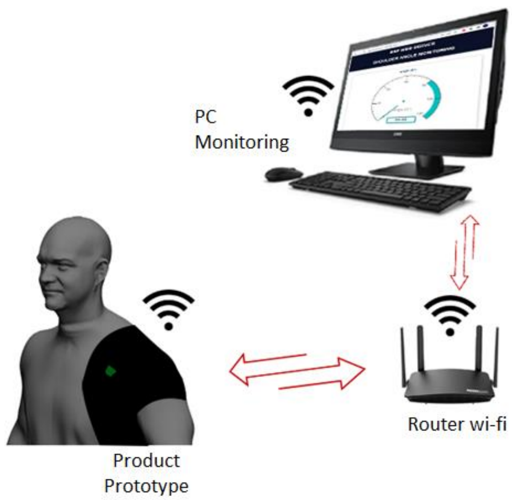

Figure 2: Shoulder posture monitoring system architecture

3.1. Hardware Design

Figure 3 illustrates the architecture suggested and circuit applications designed by using Proteus 8.9 and convert to printed circuit board (PCB) step by step, with the purpose of interfacing the flex sensor, LED, OLED and buzzer with the ESP32 microcontroller. In this design, the data pin of the flex sensor is connected to GPIO 34, which is the analogue pin of the ESP32 to collect the input data from the movement shoulder. The output is connected with GPIO2 for LED, GPIO5 for buzzer, SDA and SCL pin for OLED. The VCC and GND of the flex sensor are wired to the ESP32 voltage supply and GND respectively as demonstrated in Figure 4. Then, the written code is stored in ESP32 ROM using the Arduino IDE.

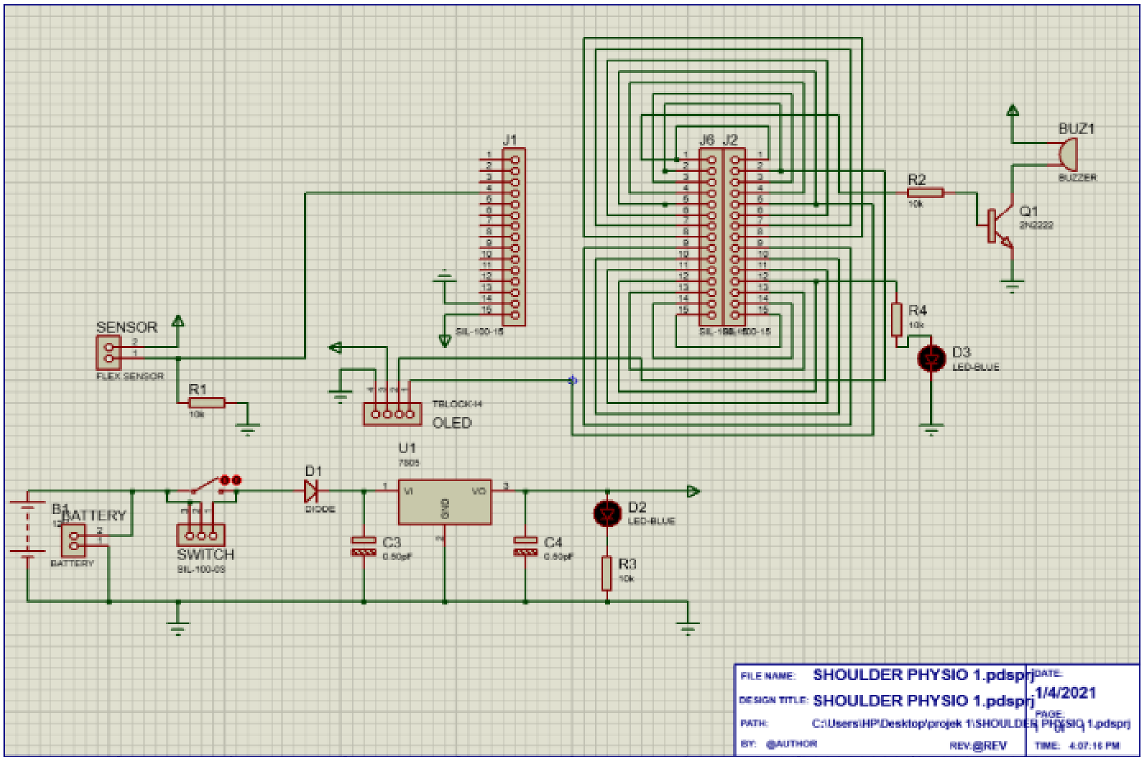

Figure 3: Schematic applications by using Proteus 8.9

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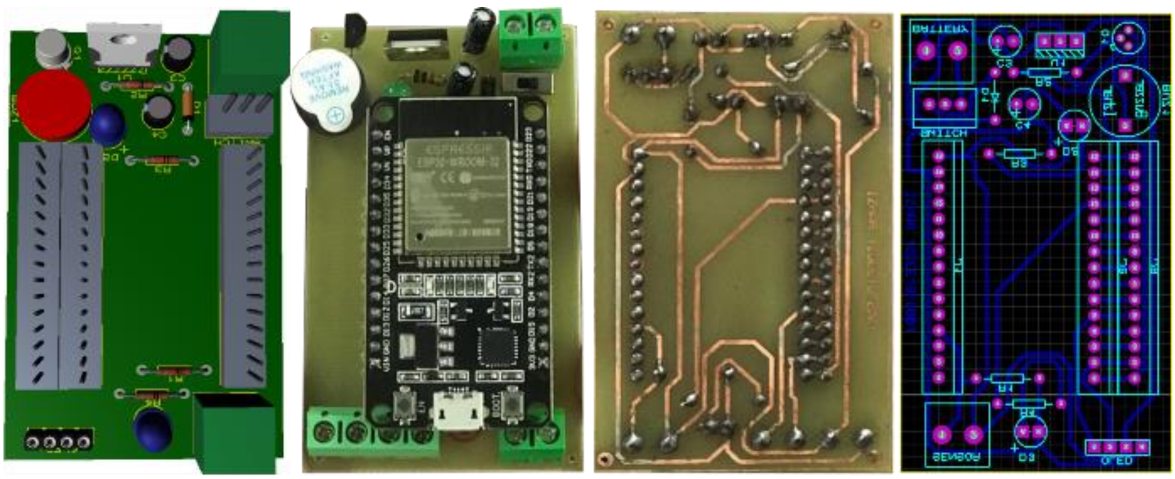


Figure 4: Fabricated PCB and complete component assemble

3.2. Software Design

Arduino IDE has been chosen to write the C code since it has the capabilities to integrate with ESP32 microcontroller and its web's system. The code is written in C programming, Hypertext Markup Language (HTML), Cascading Style Sheets (CSS), and JavaScript code and the flow of work is based on the flowchart shown in Figure 5.

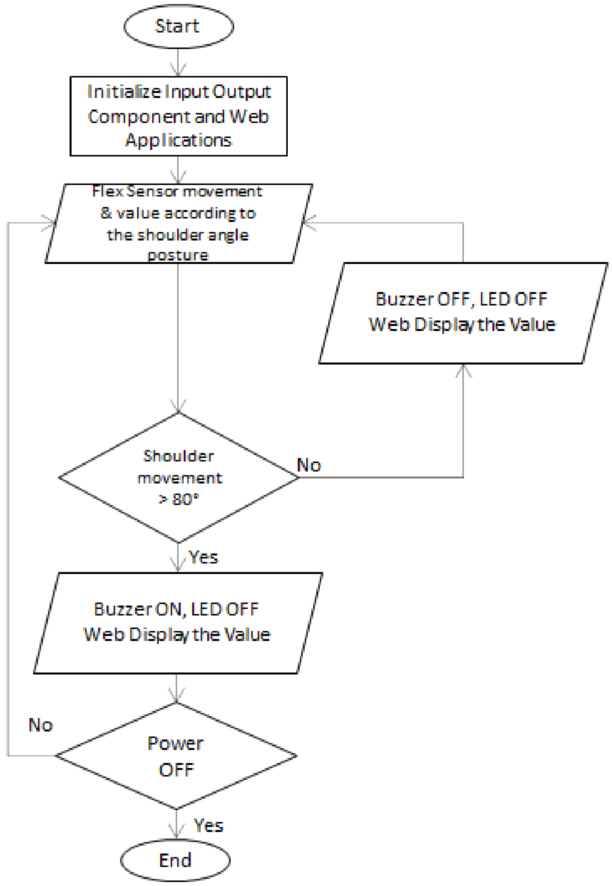


Figure 5: Flowchart for system design

The flowchart describes the details of the operation for the entire system. Flex Sensor produce analogue value then feed to ESP32 microcontroller. The ESP32 process the data feed and select the action taken based on the angle chosen and the output is issued to Web based applications, to buzzer and web to display the current angle. Figure 6 show the complete design of web interface.

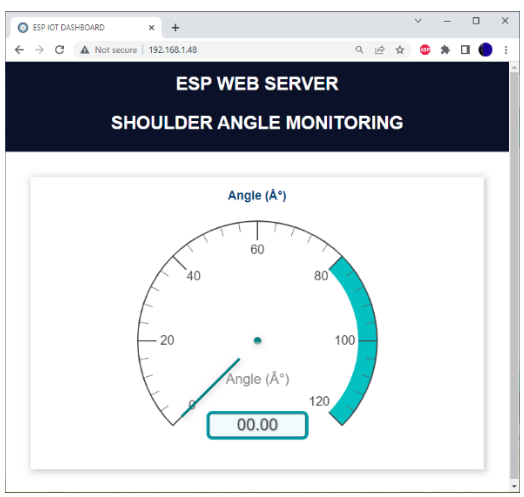


Figure 6: Monitoring web interface design

3.3. Overall Prototype Design

The production of these hardware and software design had produced the final prototype development as captured in Figure 7 and Figure 8.

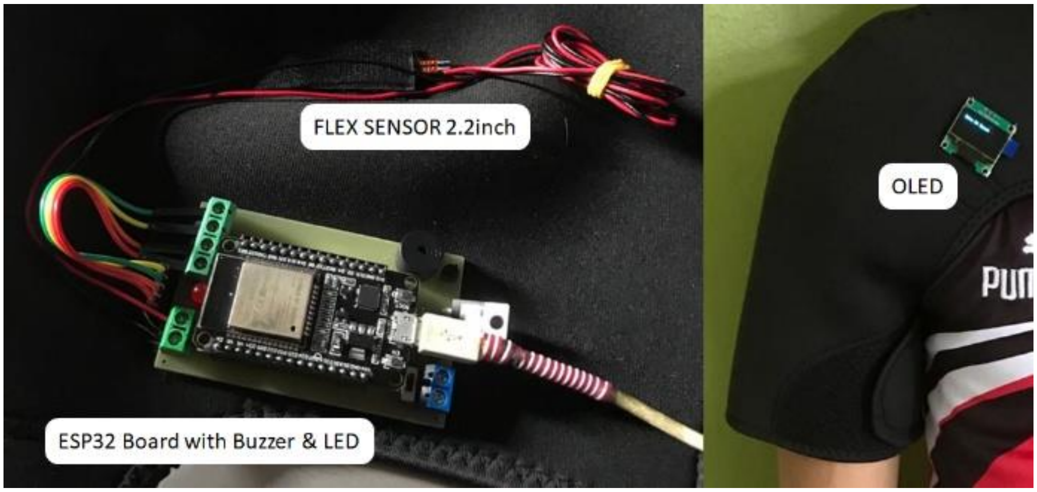


Figure 7: ESP32 circuit board with Flex Sensor, OLED and LED combined together

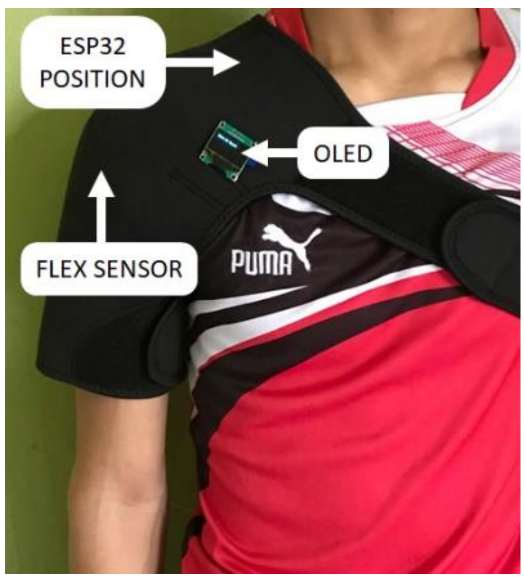


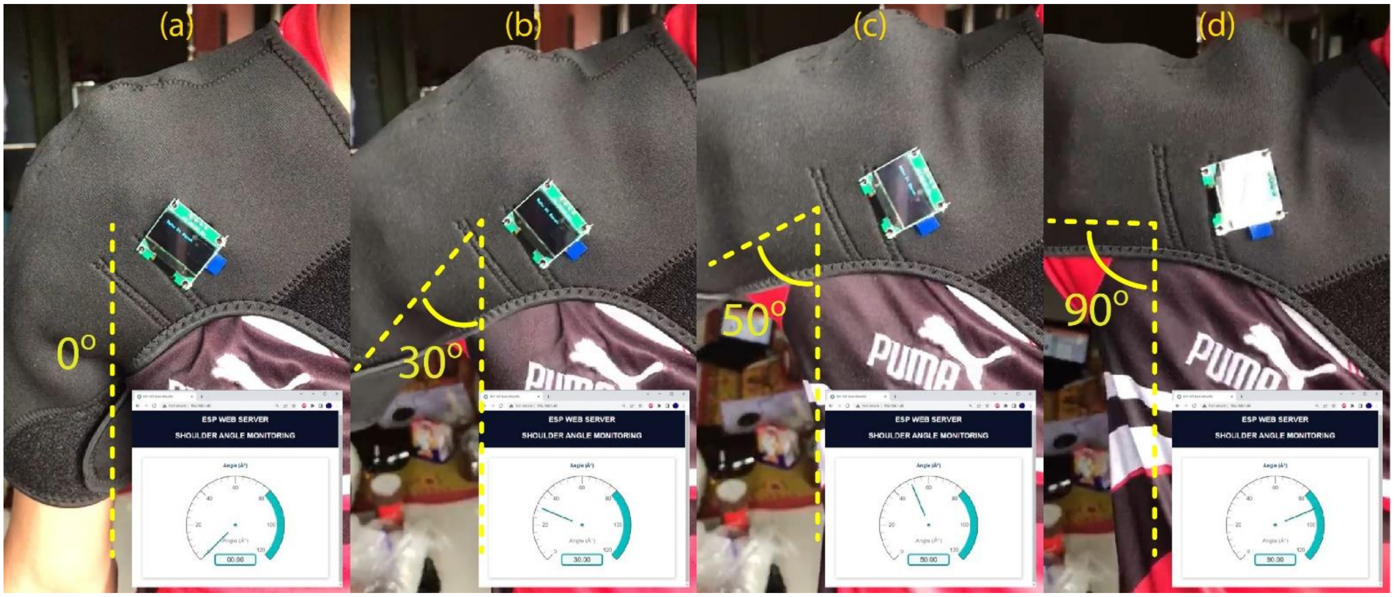
Figure 8: Full assemble on the user back position

4.0. Discussion of analysis and findings

After completing the product prototype, code sketching, and web monitoring design, the system has been tested in a real human posture to get the actual field result. The module was powered by a USB port connected to a 9V battery. Figure 8 shows the placement and testing of the prototype design. In order to monitor the results in web applications, the web must be opened through IP: 192.168.1.48 as shown in Figure 6 by using personal computer or smartphone. Then the html index inside ESP32 is been accessed. It can be accessed from any access point (AP) available. The result is produced from the flex sensor then the data is submitted via access point. From access point, it goes through to the web applications. The user can check the status through the personal computer as shown in Figure 9(a), 9(b), 9(c) and 9(d) corresponding to the user's position angle. Table 2 shows the corresponding value to the movement of the shoulder. When the movement is reach at the maximum position, the buzzer is activated (ON) to notify the patient.

Table 2: Result from the prototype tested in user back posture

Value flex sensor (Vin)	Web Corresponding angle (º)	Buzzer
1.59V	0	OFF
1.82V	30	OFF
1.82V	60	OFF



(a). 0° Degree displayed when shoulder at lowest position

(b). 30° Degree displayed when shoulder is slighly up

(c). 50° Degree displayed when shoulder is slighly up

(d). 90° Degree displayed when shoulder is same level with neck

Figure 9: Web responds to the movement of the shoulder

5.0. Conclusion and future research

The Shoulder Physio Monitoring Device Using ESP32 Microcontroller and Web Applications has been successfully established and implemented. The system able to monitor the user's shoulder posture and display via the web in real-time. It can help the user under treatment of physiotherapy to undergo the self-exercise determined by their physiotherapist alone. The significance of this project it can reduce the frequency of the meeting between the user and physiotherapist and at the same time, it will reduce the auxiliary cost related with the treatment. In the future, many more features can be added such as integrate the data at cloud for analysis purpose. This monitoring also can be used by the physiotherapist to monitor their patients from the hospital or clinic and can aid the patient to do online physiotherapist at home without physically attending the hospital appointment.

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