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Development of Smart Glove Rehabilitation Device (SGRD) for Parkinson's Disease

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Abstract: Over the past decade, significant papers have shown that rehabilitation exercise is efficient in enhancing Parkinson's disease efficiency. However, the previous devices in Parkinson Disease Rehabilitation are not very efficient as they are far too complicated, heavy in size, and difficult to conduct. This paper will focus on developing a smart rehabilitation hand device prototype using an Arduino microcontroller, to control the soft actuator by using pneumatic system and IOT system for the individual with Parkinson's disease. The actuators are designed mechanically to match and support the human finger range as it features a lightweight structure, simplistic design, cost-effective and safer to use compared to other conventional actuators. A soft actuator, accelerometer sensor, pneumatic air valve and Arduino Mega were designed as a control hardware system to operate the smart rehabilitation glove. Therefore, this study will focus on obtaining data results based on the length of the single actuator, the bending angle of the actuator based on the applied pressure, the hand position of the accelerometer sensor based on the x, y, z-axis and the suitable pressure for the SGRD rehabilitation system for future research purposes. This prototype will assist the subject's hand movement by improving the subject quality in helping the patient with Parkinson's disorder recover.

***Index Terms*: Rehabilitation hand device; Parkinson's Disease; soft Actuator; Arduino Microcontroller; Accelerometer sensor.**

I. INTRODUCTION

Studies have shown changes in the demographic profile of its population over the previous several decades, where one of the most significant scientific problems it creates is the growing number of individuals impacted by various sorts of disease as exponentially with advancing age [1]. For a population moving towards an elderly age range, Parkinson's disease (PD) is ranked second for the world's most common chronic progressive neurodegenerative illness after Alzheimer's disease [2], affecting about 3% of people over the age of 65.

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This determination is expected to double for the approaching 30 years due to the rise within the range of older people, as age is the primary key opportunity characteristic for the beginning of PD. Parkinson's disease is a chronic revolutionary neurological disease predominantly of subsequent lifestyles, related to decreased dopamine manufacturing within the Substantia Nigra and marked primarily by shaking muscle tissue, stress, slow motion, impaired equilibrium, and a shuffling gait [3-4]. Easy is known as a disease that affects the nervous system and causes human muscle tissues to come weak and their legs and arms to shake.

The reason for rehabilitation is to restore some or all of the physical, sensory, and mental abilities of the affected person that have been misplaced due to injury, infection, or illness. Evidence has also shown that strength training in Parkinson's disease is useful in enhancing clinical steps of disease progression and mobility [5]. Rehabilitation includes helping people overcome deficits that could not be medically reversed, including physiotherapy to gain movement and fitness intensity, mental health counseling, and robotic assistive devices that are instruments, equipment, and facilities that assist disabled patients to relocate and function. This equipment can help patients in their daily tasks and activities.

Several studies done by researchers have found out that robot device can play a huge role in fields such as medicine [6], rehabilitation [7-11], rescue operation and industry [12]. As per defined by researchers, robots are an automated machine that can perform all sorts of tasks and heavy works repeatedly without the limitations that human experiences. Throughout the years, industrial robots have been the essential needs for every mass production as they are designed and programmed to be multi-functional robots that can perform tasks that handles specialized materials or divisions [13]. Following the waves of the Fourth Industrial Revolution (4IR), the people of the industries demanded a medium capable of performing tasks such as controlling, transmitting and integrating various robots, irrespective of their specifications under one system, since the application of IoT was used in various ways [14]. Machine learning has increase attention and interest in robotics development. To increase the robot intelligence and functionality, embedded machine learning algorithms has been developed by latest researchers [15-19]. This will reduce the cost and electronic waste of the system while also increasing the industries productivity.

Two examples of previous devices that were developed to act as a medical assistive device are Bravo Hand exoskeleton and Haptic Hand.

Bravo hand exoskeleton is an active hand orthosis designed to support stoke patients in cylindrical gasping tasks [20].

The equipment consists of two independent degrees of freedom used to grasp the cylindrical object. The bravo hand was intended to be placed on a compact hardware and near actuators to minimize electro-magnetic interference. Only isometric circumstances can be used by the hand-exoskeleton. Bravo hand exoskeleton helps patients with actual objects that are modulated by robotic hand to perform grasping tasks. The bravo hand exoskeleton, however, is quite heavy since it is made of metal and also has a complex framework to be used daily by a patient. The use of this device usually involves guidance or therapist because it is complicated for the patient to put it on by themselves.

Haptic hand device provided a singular 2-degree of the Freedom interface robot to help stroke survivors in convalescing the hand's motor function. The physiological conditions of stroke patients may be determined by examining neuromechanical handling [21]. The different protocol preference can be chosen by specific patients because the haptic knob is stationary when the target grip strength is maintained, and rotation takes place in a one way. The Haptic Knob offers a choice of protocols that can be chosen for efficiency with unique sufferers. This haptic hand, however, is rather massive. Heavy structures and complicated designs are difficult for the patient to fully apply it.

In previous research, it is very helpful to apply a Mckibben actuator as an actuator on a rehabilitation system, because it offers countless benefits such as a lightweight actuator, a high force output per mass and reasonable costs [22]. The vigorous use of soft-surfaced actuators that can generate soft movement grows as researchers concentrating in capabilities studies in soft actuators, for instance in various robot and automation applications as it can achieve a better flexibility in their movement, in object transport, endoscopic insertion, robot gripper, Power-assisted and bio-inspired rehabilitation [23]. These developed Mckibben actuators also proven to be strong and can provide 10 times the pulling power without a slipping density friction of a traditional pneumatic cylinder of the same diameter [24]. In this research, a soft actuator with the same features and benefits substituted the Mckibben Artificial Muscle. The primary purpose of the soft actuator is to guide the endurance of this project.

Therefore, a smart rehabilitation assistive device has been developed. This device is name SGRD, which is short for Smart Glove Rehabilitation Device. The user able to control and monitor the system with IOT in a way of enforcing soft Pneumatic actuators. Thus, the bending motion of the soft actuators will assist the user finger. Furthermore, this assistive smart rehabilitation device can increase the users' productivity. The device is also safe and efficient for the user to use on a daily basis. SGRD is simpler and easy to apply compare to Bravo hand and Haptic hand It will give an advantage to Smart Glove Rehabilitation Device (SGRD) as it is more applicable and user friendly for the user with Parkinson illness.

II. METHODOLOGY

The methodology is split into three sections. The first is mechanical part, followed by the hardware part and the programming part is the final part. All part was assembling together and finally, experiments to determine the bending angle of actuator in SGRD were performed.

A. Mechanical Design Structure

SolidWorks software is used to create the design for the SGRD rehabilitation device, a solid 3D modeling package that enables users to sketch concepts with distinct designs to create 3D models.

For the main structure of the SMRG rehabilitation device is a soft and breathable glove, which is ideal for arthritis and hand fatigue user. The soft actuator was fixed on the top of the gloves on the fingers and connected to valve using pneumatic connector fittings. Pneumatic supply is used throughout the overall system.

The valve is controlled from the electronic circuit box, which consist of Arduino Mega 2560 microcontroller. The accelerometer was installed on the top of the glove in order to capture the gesture data and provide the trajectories of the hand motion. The structure of the Smart glove rehabilitation device is illustrated in Figure 1 and Figure 2.

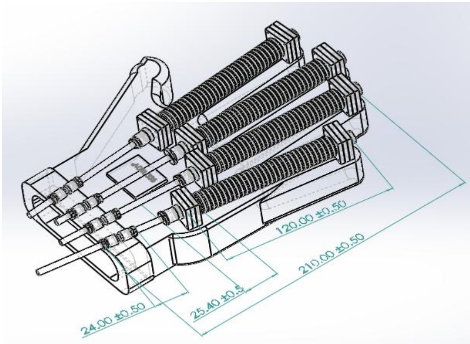

Fig. 1 Structure of SGRD rehabilitation device

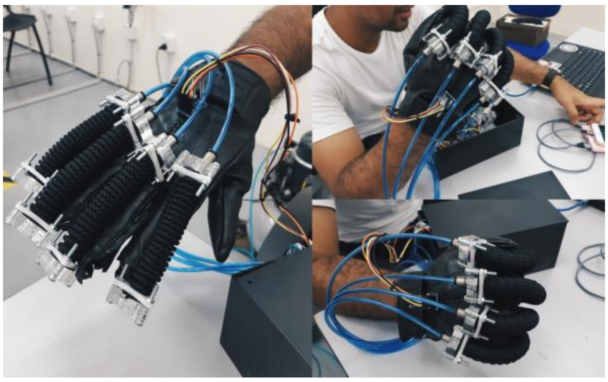

Fig. 2 SGRD rehabilitation device

B. Hardware Implementation

The electronic part of the SGRD rehabilitation device is an essential part of the rehabilitation device. The schematic diagrams of electrical component were design using Fritzing Software, which allows the user to construct a real circuit from the library part to make connections. Fig 3 below indicates the block diagram for the SGRD operation which consist of Arduino Mega 2560 as the microcontroller that is connected with other components.

The electronic circuit connections consist of an accelerometer sensor, four Channel 5v relay module, Koganei 5v valve and esp8266 Wi-Fi module.

The system is supplied from the 5v power supply to ON the Arduino Mega for data acquisition and testing purposes. The system consists of four valves actuators which are been controlled with a relay module.

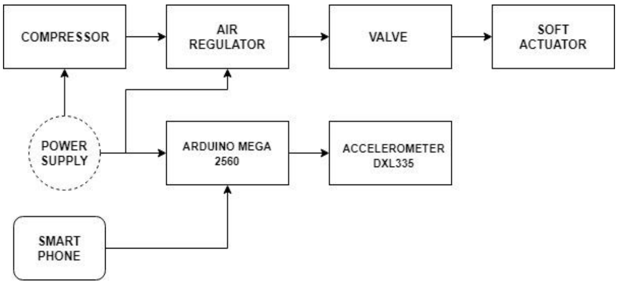

Fig. 3 Block Diagram of SGRD

1) Accelerometer Sensor (GY-61 ADXL335): In the system, the Accelerometer is installed to measure changes in user hand motion and to obtain the x, y, z-axis of hand position. The ADXL335 is a triple axis accelerometer with compact size, low power consumption and noise [25]. In working condition, it can work without any external reference or limitation. The sensing range of + /-3 g can be used to evaluate the acceleration dynamic result from each motion, shock or vibration as well as the gravitational acceleration in tilt sensing applications [26]. It has five output pin which is the reference voltage as VCC that operate around 5v, the ground pin as GND and 3 Analog output which is x, y and z. To conclude, with the stated benefits, accelerometer is obviously an optimal sensor for measuring the advancement of hand motion in terms of acceleration of motion.

2) 5v Relay Module: SGRD systems used 4 channels of 5v activation relay to control the valve. The relay allows electronics with low voltage to control high power load, from Arduino to Valve. Each relay can be configured as high 5V or low 0V. Each terminal for each one out of four relay consists of NO, NC and COM and screw terminals to control the signal from Arduino. The relay allow user to control various appliances with large current and high voltage. If the switch is 1, the system is on and if the switch is 0, it is off.

3) ESP 8266: The SGRD system is operated by Blynk Apps, linked via ESP 8266 Wi-Fi module. ESP8266 is a self-contained TCP / IP protocol stack SOC that can provide Wi-Fi access to the Arduino in SGRD. ESP 8266 is a compact size module, which is extremely cost-effective board [14].

4) Pneumatic Valve 5v: Air control valves are essential components in SGRD system. Uses an electrical current to produce a magnetic field, thereby implementing a system that controls electromechanical device to open fluid flow within a valve. For this SGRD system, 4 pneumatic valve Koganei GA010E1 is used. The Maximum pressure is 700 kPa and the energy management is DC 5 V. The operating pressure range is 0-0.7MPa and is designed for tubes with an internal diameter of 2.5 mm.

C. Control Programming

The Arduino software can be programmed in Arduino IDE (Integrated Development Environment) language C / C++. This free software enables the user to program the Arduino board and design it variously. Windows and Linux OS have the IDE accessible. The programs will process and interact with peripherals. Fig 4 indicates the program of Arduino declared input and output pin. Fig 5 and Fig 6 shows the switch code for SGRD.

```
#define EspSerial Serial1
#define ESP8266_BAUD 9600

ESP8266 wifi(&EspSerial);

int valve1 = 9;
int valve2 = 10;
int valve3 = 11;
int valve4 = 12;

int x1=analogRead(A4);
int y1=analogRead(A5);
int z1=analogRead(A6);
```

Fig. 4 Declaration code

```
void SGRD()
{

  x1=analogRead (A4);
  y1=analogRead(A5);
  z1=analogRead(A6);

  Blynk.virtualWrite(V1, x1);
  Blynk.virtualWrite(V2, y1);
  Blynk.virtualWrite(V3, z1);

  Blynk.virtualWrite(V5, millis() / 1000);
}
```

Fig. 5 Switch code

```
void setup()
{

  Serial.begin(9600);


  EspSerial.begin(ESP8266_BAUD);
  delay(10);

  Blynk.begin(auth, wifi, ssid, pass);

    pinMode(valve1,OUTPUT);
    pinMode(valve2,OUTPUT);
    pinMode(valve3,OUTPUT);
    pinMode(valve4,OUTPUT);

    timer.setInterval(1000L, SGRD);
}
```

Fig. 6 Switch code

Fig 7 below shows the flowchart of Smart Glove Rehabilitation Device using Accelerometer and Valve.

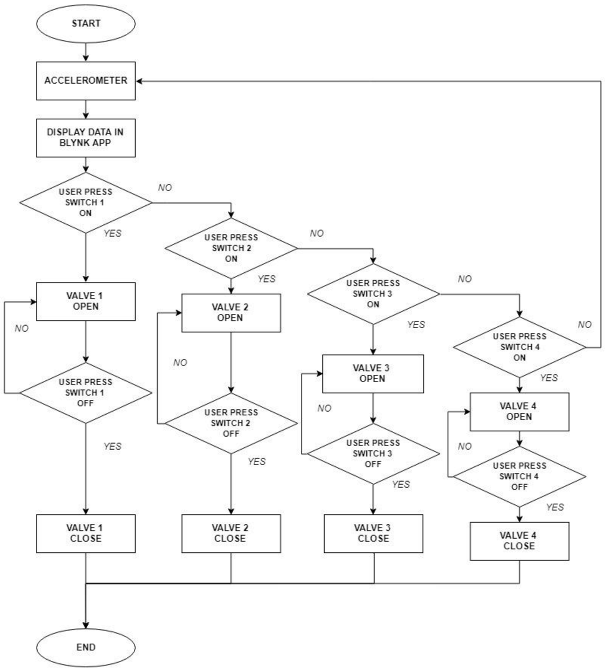

Fig. 7 Flowchart of Smart Glove Rehabilitation Device (SGRD)

The SGRD system is control and monitor from the Blynk Apps, which is built to interface with the hardware. The Blynk Apps is available in Android and IOS devices. On the other hand, the system can monitor the axis of the hand position and control the relay module ON/OFF switch button to open the valve from the Blynk Apps. Fig 8 shows the Blynk interface that allows user to control the SGRD.

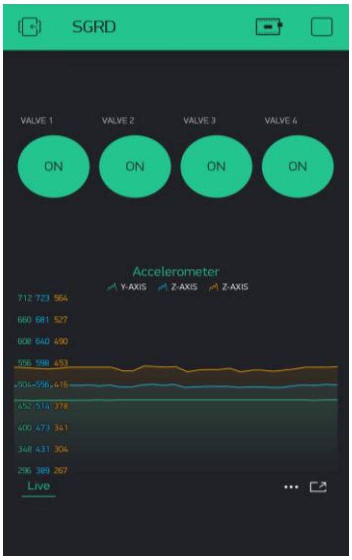

Fig. 8 SGRD Blynk Interface

III. RESULT

Smart Glove Rehabilitation Device (SGRD) has been developed to assist user that is infected with Parkinson Disease Symptom. In order to develop the SGRD, test needed to be done on a single actuator length of expansion based on applied pressure, the bending angle value of the actuator depends on applied pressure, time versus hand position and suitable pressure to run the rehabilitation device. The system is monitor and control from the Blynk apps that is connects to a smart phone.

A. Length of Actuator expansion (cm) vs. Applied pressure (psi).

Soft actuator is the vital part in constructing Smart Glove Rehabilitation Device (SGRD). Function of the soft actuator is to assist the user finger ability to improve subject quality and help to perform rehabilitation. In order to develop the SGRD, test needed to be done on a single actuator. Fig 9 indicates the expansion of a single actuator based on the applied pressure. The initial state of a single actuator is 10 cm. The actuators remain the same state after 10 psi pressure is applied. The actuator starts expending from 10cm to 10.1cm when the pressure is 20 psi and to 10.5cm when the applied pressure is on 30 psi. The actuator keeps on increasing from 11cm (40 psi) to 12cm (50 psi) and 14.6cm (60 psi) to 16.5cm (70 psi). The maximum length of the single actuator is 17.2cm as the actuators stop expending when the applied pressure is more than 80 psi equivalents to 5.5 bars. Fig 10 shows the expansion of the single soft actuator.

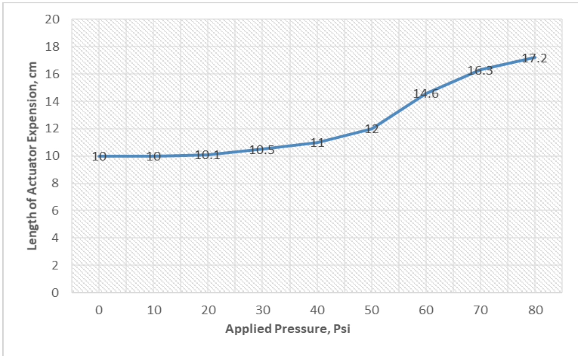

Fig. 9 Single actuator length depends on applied pressure

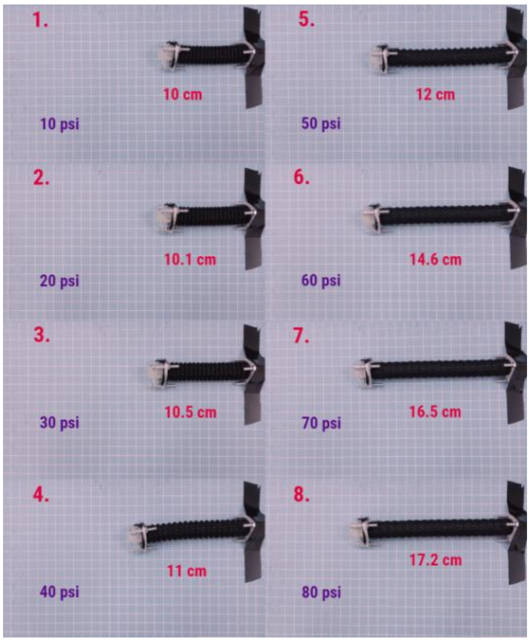

Fig. 10 Expansion of single actuator

B. Apply pressure (psi) vs. value of the bending angle of actuator (°).

Based on the experimental results of the single actuator, the actuator is directly stitch attached to a glove. Four actuators are attached on the glove. Fig 11 shows the actuator bending angle, ° by applied pressure, psi. The purpose of the bending angle is to determine the finger position of the user when wearing the glove. The actuator remains on initial state when the applied pressure is 10 psi. The actuator starts to bend to 20° when the applied pressure is 20 Psi. 50° bending angle when the pressure is 30 psi, 40 psi applied pressure in order to get 90° bending angle and 130° from 50 psi applied pressure. To get a full 180° the applied pressure should be 60 psi. The bending angle will increase when the applied pressure increase. Thus, 60 psi applied pressure is enough to develop SGRD system for rehabilitation purposes. However, it may harm and distress the user if the applied pressure is raised more than 60 psi.

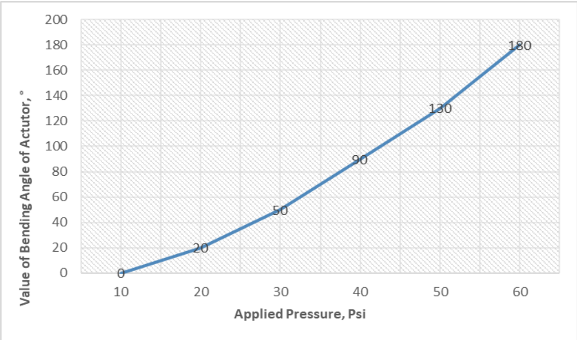

Fig 11 Bending Angle of actuator depends on applied pressure

C. Time (s) vs. hand position (x, y, z axis)

SGRD has an accelerometer attached on the top part of the glove. The accelerometer function is to detect the hand position of the user since it will give feedback in the graph from the Blynk interface. Fig 12-14 will show the time in second depends on the hand movement based on x, y and z-axis. Fig 12 show the user hand position at normal state when using the SGRD. Fig 13 and Fig 14 shows the hand position of user if they decide to move on the left and right-side state. However, the axis will be changed occasionally based on the user movement when they put on the SGRD glove.

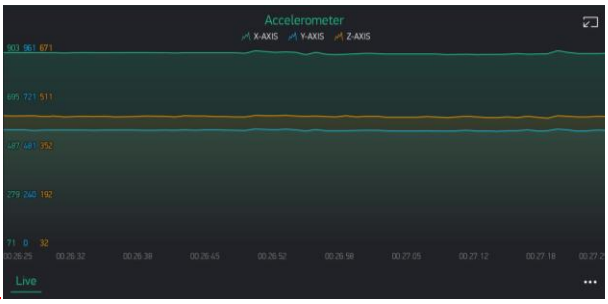

Fig. 12 Hand position on a normal state

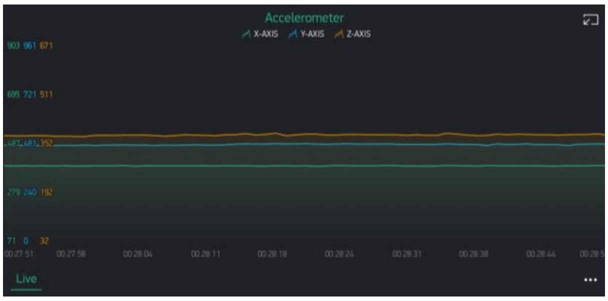

Fig. 13 Hand position on a right-side state

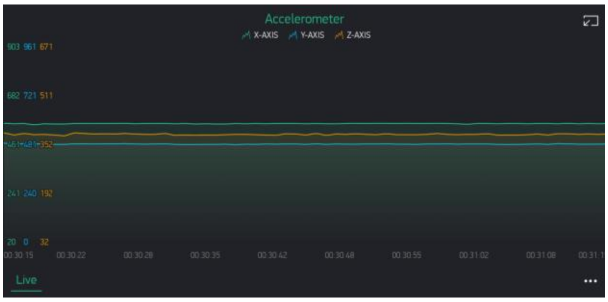

Fig. 14 Hand position on a left side state

D. SGRD testing on user

The SGRD had been tested to 10 users in order to gain their comfortable state of hand when conducting the rehabilitation process. Fig 15 shows the pie chart for 10 tested user's feedback data. 7 out of 10 agree that the suitable pressure to run the Smart Glove Rehabilitation Device (SGRD) is 60psi. 2 out of 10 agrees that the pressure should be up to 70psi as it is more helpful to user since it gives higher pressure. 1 out of 10 disagree as the user prefer to use low pressure with 50psi considering as it is already enough pressure to conduct hand rehabilitation with SGRD compare to 60psi and 70 psi. Therefore, it can actually be concluded that 60 psi is the best applicable state for user with PD disease as it gives the most suitable pressure and will not drive the user disabilities.

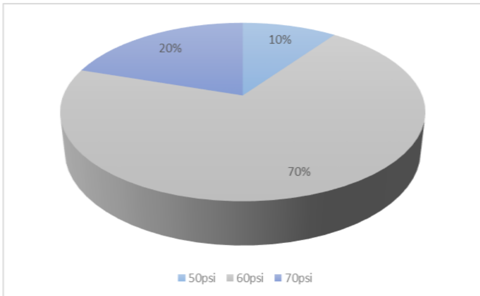

Fig. 15 SGRD hand testing

IV. DISCUSSION

This project is focusing on the development of smart glove rehabilitation device for Parkinson Disease (SGRD). In this section, the SGRB bending angle will be discussed. From the results, Fig 16 shows the bending angle for each applied pressure to the SGRD.

The soft actuator received the pressure 10psi (1), 20psi (2), 30psi (3), 40psi (4), 50psi (5) and 60psi (6) from the compressor and starts bending. The bending angle is measured with a ruler and protractor. Starts with placing the ruler and place the midpoint of the protractor on the vertex angle. Hence, read the degree on the number scale. The soft actuator needs at least 20psi to start the bending. To achieved a full 180 bending angle of the soft actuator the compressor air pressure should be at 60psi equivalent to 4 bar.60psi is the suitable optimum pressure for user to use as the pressure applied increase, the greater the force of the actuator. It slightly may cause injuries and affliction towards the user.

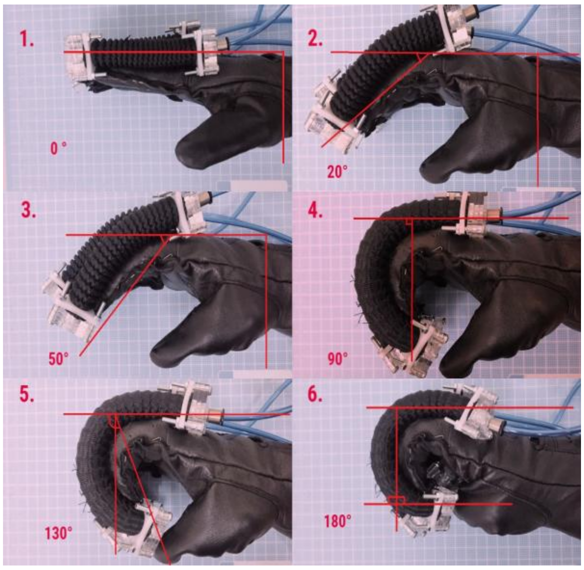

Fig. 16 SGRD Bending Angle

On the other hand, the SGRD could also determine the user hand movement. The accelerometer will detect the rate of change motion of the user every 8 seconds. The changes of hand movement will be determined by the graph according to differences value of x-axis, y-axis and z-axis. As the user hand moves, reading of the accelerometer sensor will keep on changing. Fig 17 below illustrates each user hand position state at normal (1), right (2) and left (3) state.

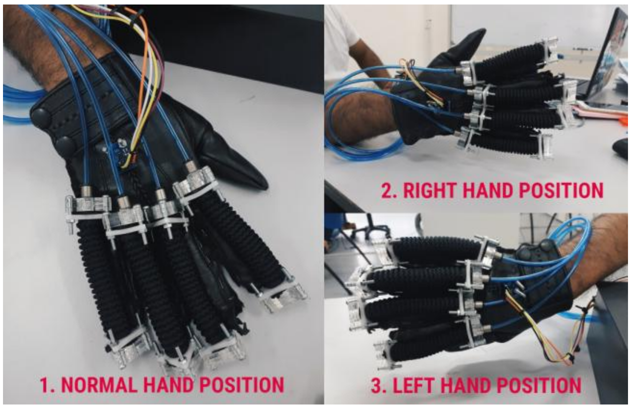

Fig. 17 User state of hand using SGRD

Limitation for the system is that the system is not portable and can only be done with a presence of a compressor that is to supply the pneumatic air in the soft actuator. The soft actuator also needs to be stitch orderly to the glove due to the expansion of the soft actuator that might detached from the glove. Constant instruments failure is also the major limitation for the whole SGRD process as some components and item are defects and need to be carefully handle while testing.

Overall results shown that SGRD is successfully achieved which are:

1. The IOT platform of the Blynk apps from the smart device that controlled the Arduino microcontroller can control and monitor the user decision either to switch on or off the valve.
2. The usage of soft actuator that is simple cost effective and safe in hand rehabilitation.
3. Data results achieved on the length of single actuator, the actuator bending angle based on the applied pressure, user hand position based on x,y,z axis and the suitable pressure for user on using SGRD rehabilitation system.

V. CONCLUSION

The research aim at development of a new technique of using a soft actuator and control system that can guide user to perform a physical hand rehabilitation. SGRD has been developed successfully and have great features as it can guide user to perform the process of recovery. Other than that, the SGRD has an ability to detect the hand position of the user since it will give changes in the graph from the Blynk interface. The user can control and monitor the device as the device is connected with an IOT platform. However, the SGRD can only perform to guide four fingers as only four soft actuators attached in. As for conclusion, the project entitled ‘Development of Smart Glove Rehabilitation Device for Parkinson disease’ has successfully accomplished its purpose and objective.

In the future, we are planning to attach another type of actuator such as Mckibben actuator to each finger and manipulate on other hand by using master and slave technique for this rehabilitation process. Moreover, sensor such as pressure sensor and heartbeat sensor can also be attached to the system. Instantly later, this method can be applied to the real user that affected with Parkinson Disease.

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