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Wireless Plantar Pressure Distribution Monitoring System

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Abstract: The person's foot sole posture during the running period can be incorrect as no training beforehand. They need to be trained and monitored by the professional instructor throughout the movement. This training to achieve the sprinter with correct posture and technique during a running session. Wireless plantar pressure distribution monitoring system uses the latest processor to comply with the fourth industrial revolution (IR 4.0). The system has recorded the pressure distribution of the sole during the activity for monitoring purposes. The Force Sensing Resistor (FSR) is used to detect the pressure applied during the training. The FSR will is placed on the insole at the heel area. The user can operate the device wirelessly indoors and outdoor. The research is covered three methods, which are running together with jogging and walking. Two techniques are applied in the routine to optimize the running acceleration, which are plantar flexion and a longer stride. The research finding shows the time taken to finish the track after applied both techniques are reduced. The force on the heel is reduced as it accelerates because the methods apply only focusing using the forefoot. This model can be used to monitor the pressure distribution of plantar during running. In the future, the system is accessible online and offline with numerous sensors allocate on the subject sole.

Keywords: Internet of Things, plantar pressure, medical devices, running, jogging, walking

1.0 INTRODUCTION

The human can walk and run freely without any manual or operation guide. The method use may be incorrect and impractical compared to the professional sprinter. A device is built to identify the pressure distribution of the sole foot during the session, but it is limited to walking pace simulation. A new product needs to be designed to replace the existing product in the market.

The area distribution of foot sole can be distinguished from the analysis for clinical purposes. During the clinical purposes, the parameter of plantar pressure distribution, physiological and pathological information of a patient is gathered. However, the techniques of human walking and running can be different individually [1]. The primary purpose of this project is to monitor the plantar pressure distribution by using the pillar technology of IR4.0. The device can be diagnosed wireless by a user with an application in the smartphone. The wireless monitoring system uses the Raspberry Pi microcontroller. The Raspberry Pi is the latest interface and follows the Industry Revolution (IR) 4.0. The system is wireless that connected to a monitoring app on the smartphone and a computer. The aim is to monitor the plantar distribution of the sole of the athlete during running. The person's foot sole posture during the running period can be incorrect as no training beforehand. The patient needs to be trained and monitored by the professional instructor throughout the movement. The monitoring system available is only limited to walking pace and bulky in size, made the machine stationary. The device connects to the computer with any tethering wire, so not wireless to test outdoor and is not compatible with running pace.

This study aims to record the behavior of plantar pressure distribution of the respondent during training. Then, design and develop a device that implements the internet of things (IoT) by following Industry Revolution 4.0 using the wireless method. Lastly, to monitor the plantar pressure distribution with the application available on mobile phones and personal computers.

2.0 RELATED WORKS

Previous researches focused on walking routines and stationary, walking platforms [2]. The walking platform is collecting the plantar pressure applied by the subject. The subject is in barefoot condition and restricts to few steps only. Therefore, the subject technically does not perform as they walked every day, without attaching to any device or during a physical rehabilitation program [3]. The graphic user interface (GUI) uses Microsoft Visual Studio to display the data collection for every single training [3].

This application needs a therapist experienced in clinical rehabilitation to interpret the GUI only displaying the data without automatically diagnosing the subject [4].

The technological innovation in the fourth age is the Internet of Things (IoT), a system that can be remotely detonated or tracked worldwide [5]. The probability for IoT is unregulated in large technology realms. The sectors include retail, consumer, industrial, automotive, environmental, agriculture, military, and medical[6]. According to the IoT architecture, [7] the components are classified into three functional units: Internet, Things, and Semantic Oriented.

The application of IoT in the health industry is vital to improving quality and service. The application in this industry is also economical because the cost implemented is reducing[8]. Moreover, the sensing input technologies in wireless networks upgrade the development and operation in this industry[9].

The study discussed on Plantar Pressure System Monitoring System. Comparison of plantar pressure distribution between three different shoes and three general movements in futsal studied by [10]. This is advantageous to the trainer who needs explicitly to buy suitable shoes for each representative player in the team as the data extract details. The pressure recorded is categorized in 10 regions of the sole of the player. Next, it aims to create an economical device that completes all the parameters of monitoring human gait [11]**.** The study only focuses on walking. The study by [12] is to create a device that studied the effect of foot pressure during running and also the arch foot affect the speed. The research is using Arduino Uno and focusing on the arch of the subject during gait.

3.0 METHODOLOGY

The system architecture of the Plantar Pressure Monitoring System shows in Figure 1. The input is a Force Sensitive Resistor that detects any forces applied to the sensor. The input signal is converted from analog to digital by MCP3008. The Raspberry Pi 3 B+ is used to process and transmit the data wirelessly to the Node-RED dashboard. The Raspberry Pi uses PINENG PN-965 10000mAh Lithium Polymer Power Bank during the routine session and can be USB powered by laptop serial port for monitoring purpose

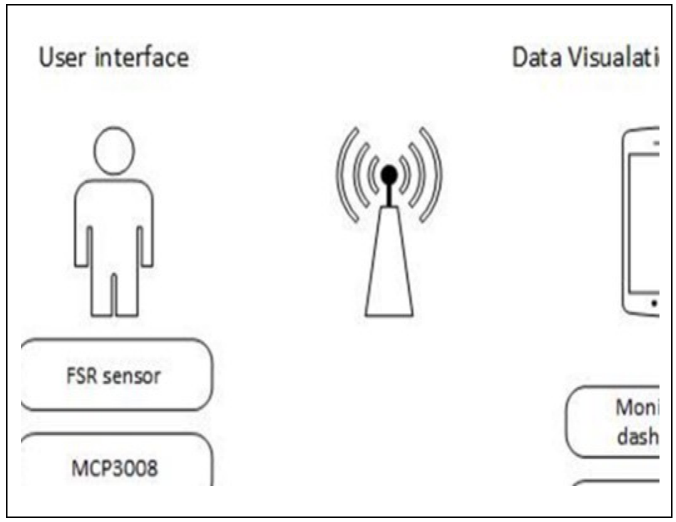

Figure 1: System architecture of Plantar Pressure Monitoring System

3.1 Program flowchart

Figure 1 shows the program flow chart of the Plantar Pressure Monitoring System. Firstly, the Node-RED dashboard displays on the smartphone. Then, when no subject movement is detected, the cloud data will display on the dashboard. This data is for experts to diagnose after the routine session early. Then, for the routine testing, the Raspberry Pi 3B+ uses powered by Lithium Polymer Power Bank. The subject will run for 50 Meters, and it applies to the repeatability of pressure used on the FSR.

Next, the input signal from FSR is in the analogy signal will convert the signal to digital, using MCP 3008. The signal then transmits to the Node-RED dashboard to display the recorded data via a Wi-Fi connection. Finally, the data are saved in the Pi storage log for future diagnosis.

3.2 Testing Method

The subject is wearing the sling bag together with the device. Figure 3 shows the sling bag is to secure the device from loose and slip down during the routine. The device is powered with the Lithium Polymer Power Bank and with Hotspot connectivity. The mobile phone and the device use the same network. Thus, the user can operate and VNC server and viewer. The sling bag is worn at the waist to minimize the shaking during testing. The prime place of the sling is at the back of the waist

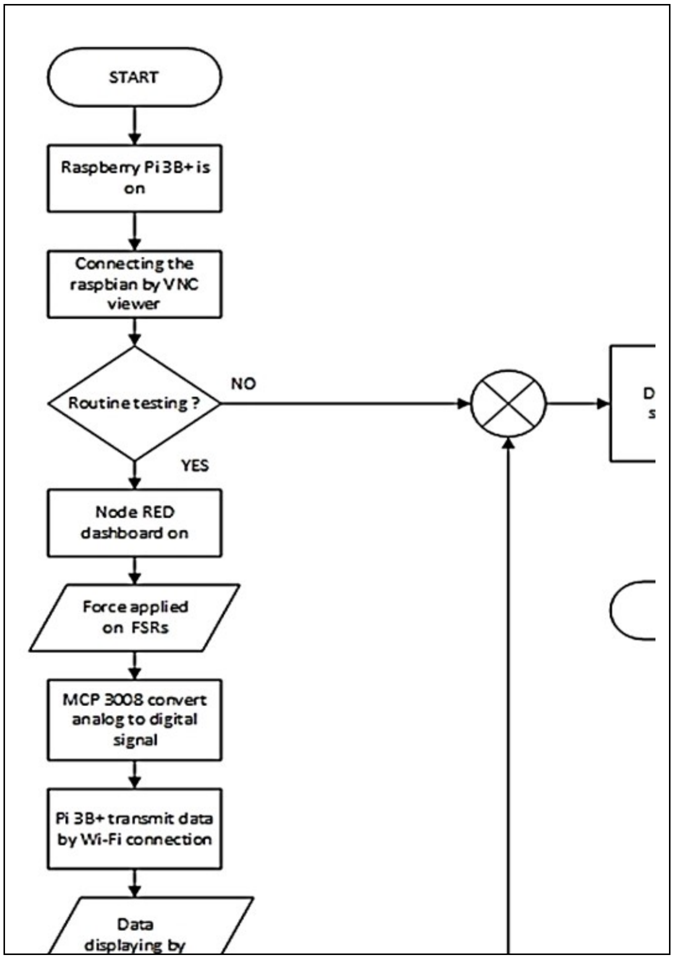

Figure 2: Program Flowchart

Figure 3: Subject wearing the sling waist bag

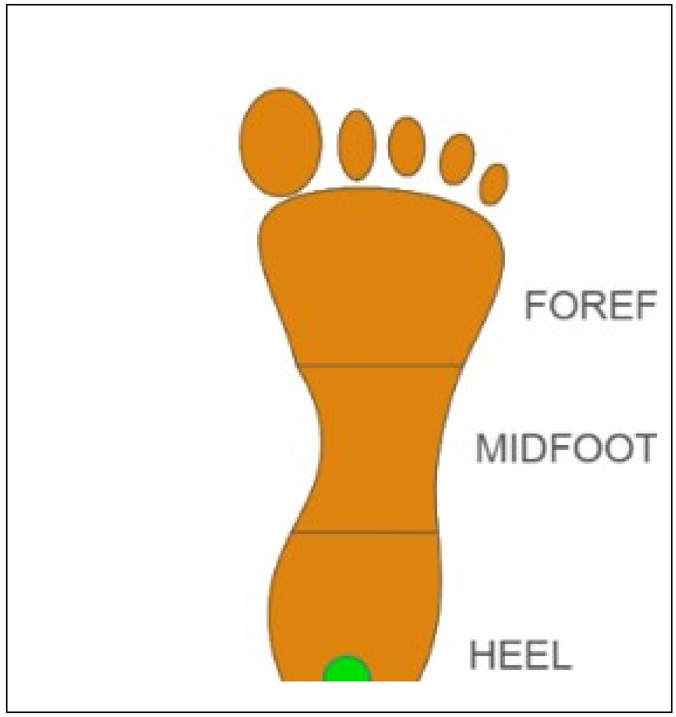

Figure 4: Sensor mapping

Figure 4 shows the FSR placing at the heel area. The heel is chosen as the runner only focuses on the used forefoot in testing the tester overview with the device shown in Figure 5. The track 50 Meter is measured with a laser measuring device. The track used is a non-busy neighborhood alley.

3.2 Data Recorded Analysis

Formula (1) calculates the data and extracts it by the C language programming. The data recorded are in the analogy value. The analogy is 10 bits which are equal to 1024 discrete analog levels. To digitalize the output code calculation,

$$digital\ output - \frac{1024 \times V_{IN}}{V_{REF}} \qquad (1)\ [2]$$

$V_{IN} = Voltage\ given\ to\ MCP3008$

$V_{REF} = Voltage\ reference\ applied\ to\ MCP3008$

The digital output represents the pressure applied to the FSR sensor. The maximum threshold of the entire force on the strip is 1020bits. The V_IN and V_REF are supplied with 3.3V. The result obtained is the digital value of the pressure data from the FSR sensor.

$$1024 \div 100 = 10.24\% \qquad (2)\ [2]$$

In the code, the set volume variable is calculating as

$$set\_volume = \frac{pressure\ applied}{10.24} \quad (3)[2]$$

As a result, the data stored is recorded in the percentage together with the time taken.

Figure 5: The device

4.0 RESULT & DISCUSSION

4.1 Plantar Pressure Monitoring System.

The subject will run the Raspbian desktop on the mobile phone with hotspot connectivity as routine testing is conducted outdoors. Then, the VNC viewer is connected to a VNC server of Raspberry Pi. Node-RED applications are clicked, and the dashboard is displayed on the node-red user interface. Start by opening the Raspbian desktop and follows by selecting the Node-RED application in the menu. The flow of the system is shown, and edit the name of a storage log as desired. Next, open the dashboard User Interface as Figure 6, and the dashboard will display the pressure system. Press the start button before the start, and the line graph is shown on the UI after completion testing. The saved routine log is saved in a testing folder for further reference, and the routines are kept in the log file.

4.2 Measurement Plantar Pressure Data

The subject runs on 50 Meter track. The quality of the can be affected due to exhaustion and fatigue. Therefore, multiple testing was conducted to collect the data to increase the accuracy of the collected data. The subject is undergoing multiple testing for a few days. The subject applies few techniques until the time taken is reduced drastically.

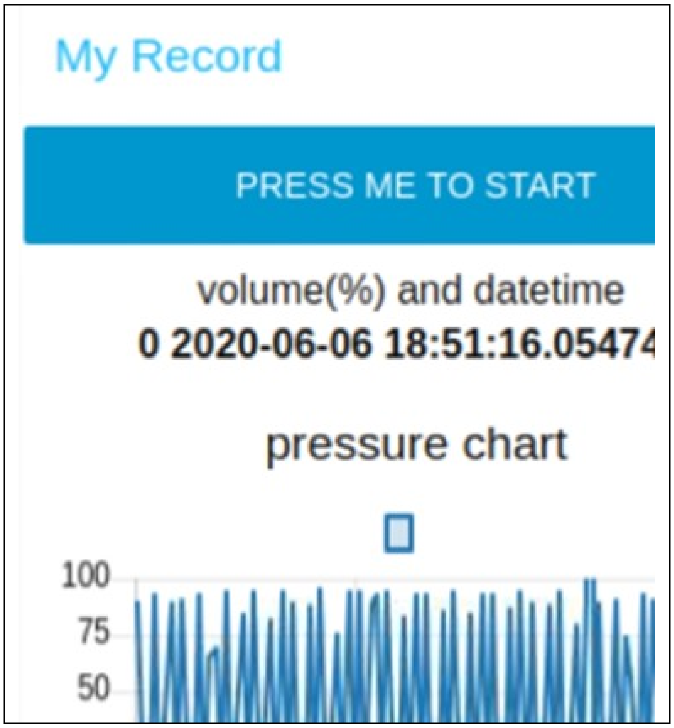

Figure 6: The dashboard of the Plantar Pressure Monitoring System

The best of five testing data is collected. The selected routines represent the most stable output graph of the percentage of the pressure applied—Interval of collected data in second and milliseconds. The time delay of the FSR to record the force is only 0.5seconds. This made the graph unstable and irregular because the FSR sensor read the pressure of sole on the air during testing and skip reading the applied force if there was no pressure during the time cycle. The final routine has the least number of time taken of each sensor to detect the force applied.

Figure 7 shows the first routine graph. The time taken to finish the track takes time 11.83 seconds. The time taken is longer as no technique practices during the testing. The time is taken in 4.56 - 6.57 seconds, and it is due to the sensor detect the pressure of soil in the middle of the air. The graphics are slightly decreasing due to the pace increasing and using more forefoot than the heel.

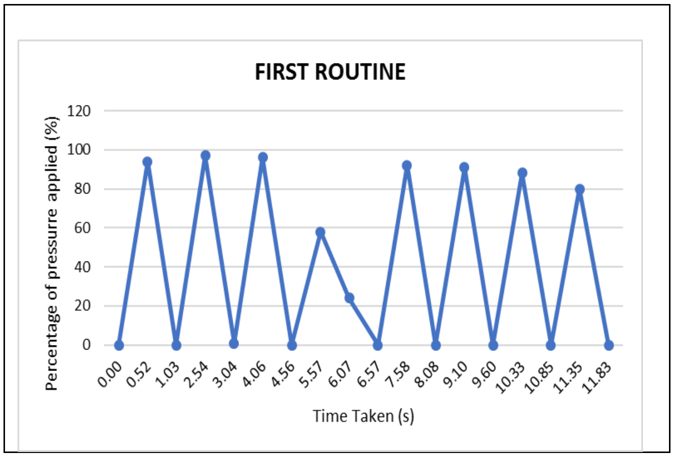

Figure 7: Percentage of pressure recorded when no technique applied during running routine

Figure 8 shows the third routine where one technique on plantar flexion is added to the subject's movement. The plantar flexion is the maximize approach of using the forefoot during the contact phase in the running. The graph decreases as finished as the running becomes more as the subject is more stable on the running session. The force recorded data are becoming lighter as the heel pressure is less in contact with the ground after a few seconds of the starting point.

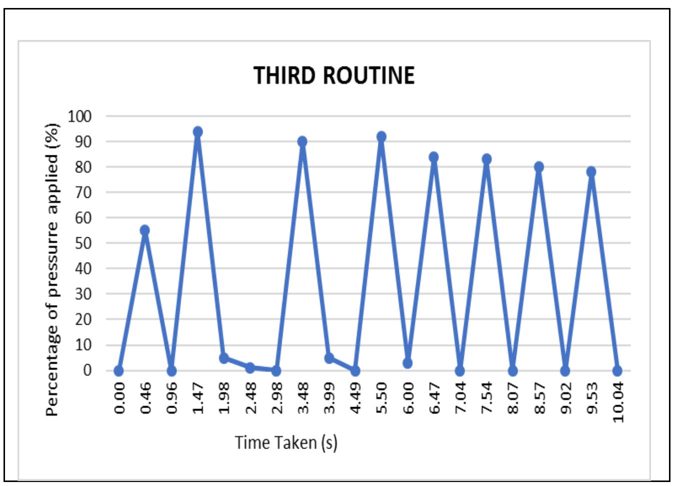

Figure 8: Percentage of pressure recorded when plantar flexion technique applied on running routine

Figure 9 shows data of cases where the technique of strides is applied to the testing method. First, the strides are widened, and therefore, the ground contact area is reduced. The final graph recorded that only five contact phases for the right foot in 50 Meter track. Consequently, it is proven the stride is longer than the first three testings.

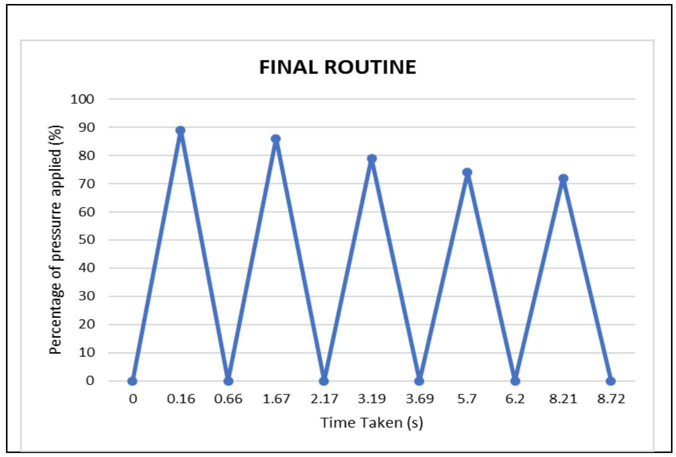

Figure 9: Percentage of pressure recorded when plantar flexion and more prolonged stride technique applied on running routine

Table 1 The Result of Running in 50 Meter track

Routine	Technique(s) applied	Time taken (SS:MS)	Final Pressure (%)
1	No technique	11:83	80
2	Plantar flexion	10:40	80
3		10:04	78
4	Plantar flexion and longer stride	10:22	77
5		08:72	72

The recorded time taken in Table 1 is now being average for a girl to finish in 50 Meter track. To conclude the five recorded routines, the techniques added can optimize the runner to finish the track as fast as possible. The table is the conclusion of the recorded time with applied techniques.

4. 3 Comparisan between Three different mode of testing (running, slow jogging, and walking)

The experiment is continuing to vary the result recorded. The testing then is doing multiple testing by running, jogging, and also walking. The distance for the testing is limit to 50 Meters. The subject also placed the sensor on the right foot heel to measure the force applied during the testing mode. The graph for walking (Figure 10) is put secured together. Every 0.5 seconds, record the pressure applied on the FSR.

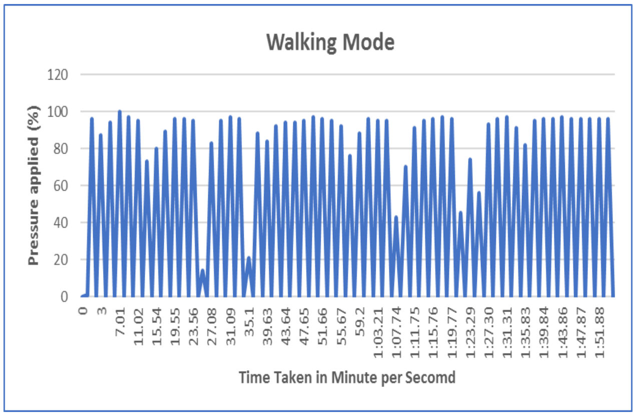

Figure10: Percentage of pressure applied on FSR versus the time taken for walking mode

The jogging graph in Figure 11 is done with no technique is applied. The data force distribution is not uniform due to the irregular pace. The time delay for FSR to operate is only on the high force applied, make the 4.04 to 6.04 second only detect the high digital output. As the running graph, Figure 12 is the final routine data.

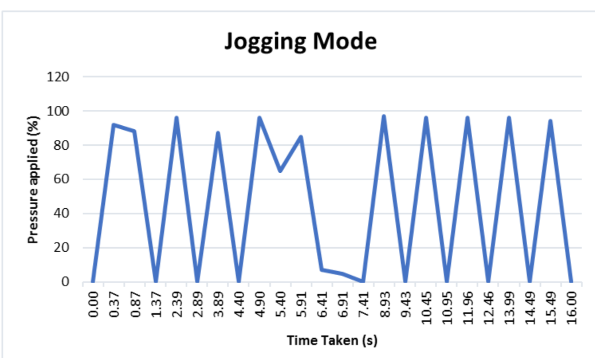

Figure 11: Percentage of pressure applied on FSR versus the time taken for jogging mode

4.4 Comparison from the previous study

The study from [13] is only focusing on the biomechanical sprint technique of international sprinters. The method discovers by the researcher applies to the routine. The study is only studying the behavior of the athletes by using the motion camera and cover the entire body angle during the running session. No force is measured during the study. The discover techniques are recorded to apply in the routine.

The previous study is only focused on the influence of the velocity on the voltage determined by the specific arch form [12]. The experiment was done in the walking method, and the testing area is indoor. The IoT used is Arduino UNO. The sensor is used in the experiment to measure the voltage applied by the user with a different arch form. The current study was using the latest IoT, which is Raspberry Pi 3 B+. Combining both types of research, Wireless Plantar Pressure Distribution Monitoring System created a new system for monitoring purposes in the running method. The system also can monitor other activities such as walking and jogging.

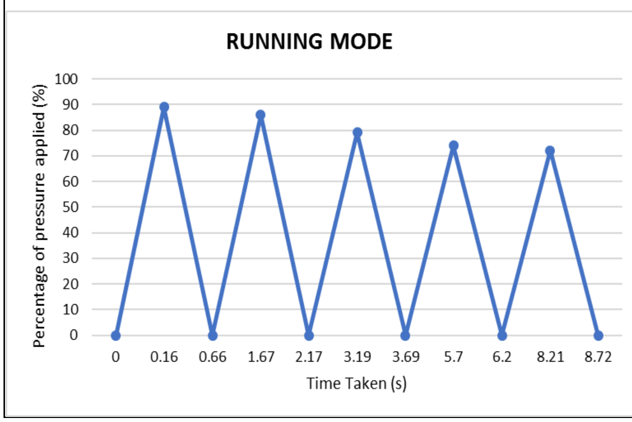

Figure 12: Percentage of pressure applied on FSR versus the time taken for the running mode

5.0 CONCLUSION

The Wireless Plantar Pressure Distribution Monitoring System has achieved the objectives of the study. The system is providing a device to monitor the force applied by the subject during kinematic movement. In addition, the forces from the analog value are converted to digital for review in the pressure system in the Node-RED dashboard.

The data is also stored in the Pi storage log for further review and consultation. The Raspberry Pi 3B+ is used to implement the IR4.0. The Pi provided wirelessly to support the device and connected to the server to view the dashboard in the smartphone. The device is also accessible for a personal computer for the review and consultation session. The plantar distribution monitoring system using the Raspberry Pi processor, the system is advanced and can be used widely in the sport and medical industry. The study also concluded that flexion technique will produce high percentage of pressure toward the device.

6.0 RECOMMENDATION

The system has achieved the objectives, but the system is limited technology. There is recommendation can be improved to upgrade the present system as below;

a) Increase the used of number of sensor and it can maximize the sensor's precision to read the force applied during the routine.

b) The device can be used in offline mode. It can be helpful for the training in no service provider area and save the cost for subscribing to the internet to support the viewer device and hardware.

c) The number of subjects is a variety to two or more categories. It can be widening the analysis data. The study can be more precise and variety of the subjects.

d) Apply the usage of more reliable sensor to prolong the life span of the devices quality.

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