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Medical IoT Development of Pilgrims Health Monitoring System for Hajj and Umrah

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Abstract: The increasing numbers of pilgrims each year make the Hajj seasons is more challenging especially in health services. The number of health services during Hajj season is approximately 32,000 peoples. By ratio, 1 labor force in health sector need to cater 73 pilgrims at a time. Not only that, the risk of disease is came from the effect of hot weather. Due to the problems faced, this project is aim to design and develop wearable Health Monitoring System for Hajj and Umrah Pilgrims, monitor two health parameter which is skin hydration and cough detection with a low cost system that promote the usage of Body Area Network (BAN) and Internet of Things platform. As this development is focusing on skin hydration and voice obstruction recognition, input sensor connected to the microcontroller act as a processor and coordinator from the input sensors to the user with the integration of Wi-Fi to analyze the data in real time through smartphone applications and cloud database. When the input measure passed the threshold limit, the wearables and smartphone application will notify the end user and the data can be access and stored on cloud storage. IoT implementation in Medical Healthcare practice especially in remote health monitoring would be beneficial for both party consumer and provider. However, this develop is intended to gives an early detection to the user only.

Keywords: Skin moisture, Voice recognition obstruction, Coughing , Hydration

1.0 INTRODUCTION

The increasing numbers of pilgrims each year from all over the world make the Hajj seasons is more challenging in so many aspects especially in health services. Reported on 2018 Hajj statistics, the number of health services during Hajj season is only 32,579. If we're comparing by ratio of the pilgrims during that year, approximately 1 labor force in health sector need to cater 73 pilgrims at a time. It is impossible for 1 health worker to cover that amount of pilgrims at a time if they facing health problem during the Hajj ritual. The government of Saudi Arabia providing free healthcare to all the Hajj pilgrims during Hajj seasons, 27 hospitals total in Mecca with total of 5,038 beds capacity and 154 centers at one time and another 11 hospitals are set up in Madinah dedicated to pilgrims. The numbers of hospital and services still not enough to cater large amount of congregation if the numbers keep increasing. Not only that, during the mass gathering at Mecca, the density of congregation crowd can lead to distribution of disease easily because of the crowd can increase to seven individuals per m^2, indicating overcrowding of the congregation at a time. Pilgrim who are performing Hajj and Umrah are openly exposed to the varied and compelling health risk due large amount of crowd, confined space, unhygienic practices among the pilgrims, close contact during the event as well as international travel [2]. Without realizing it, these outbreaks and spreading of infectious disease could lead to global health crisis during and after hajj season.

Another challenges that pilgrims will be facing is unpredictable weather which is the temperature can be as low 38°C and as high 55°C with relative surrounding humidity of 25% to 50% and can be categorized as low humidity [3]. With that kind of weather, the probability to get heat stroke is high in addition with the density of the crowd increasing the risk at a higher stake. The risk of heat stroke and dehydration of water inside the body, is the beginning development of various infectious disease by 37.5% which is are respiratory disease, heat stroke or heart attack, gastroenteritis, skin disease and dried eyes and high fever; chronic disease encountered by 62.5% which is diabetes, hypertension and heart disease. In medical and healthcare services, as much as half million pilgrims are receiving health services and care from the health workers and as much 400 pilgrims are warded because of comas and unable to complete their Hajj and some completed their Hajj ritual through medical mobile. Some of comatose pilgrims taken to Arafah by ambulances and successfully completed their Hajj.

From this case scenario, it is proven that there is not enough number of medical practitioners/workers to serves some big amount of pilgrims throughout the Hajj season.

Therefore, making this situation much worst to monitor health of the pilgrims individually efficiently. In additional, during the Hajj season, temperature in Makkah is between 38 to 55 degree Celsius with relatively surrounding humidity of 25% to 50% thus it will cause chronic disease such as respiratory disease including sore throat and asthma, heat stroke and skin disease. This case scenario gives an idea to develop a wearable device that can monitor each pilgrim health condition individually in efficient way. To be remind that this development of the project is intended for early detection, not to prevent the disease in pharmaceutical way. This is an effective health monitoring wearables and information management system could prevent or control the dissemination and outbreaks of disease among the pilgrims during and post Hajj personally without the burden of the medical practitioners or health services.

2.0 METHODOLOGY

2.1 Block Diagram

The project development consists two input measurement parameter which is to measure human skin hydration and coughing detection. Both are connected to the microcontroller ESP32 TTGO Node MCU act as a processor and coordinator from the sensors input connected to the microcontroller act as a processor and coordinator from the input to the user output with the integration of Wi-Fi to analyze the data in real time through smartphone applications and cloud database The block diagram of this project consists of input which is the two measurement sensor for skin hydration and coughing detection, process for the microcontroller ESP32 TTGO Node MCU and output is smartphone applications using Blynk and IoT platform using Google Spreadsheet act as server cloud database. The result is displayed in numerical number based on parameter. Skin hydration will display percentage (%) of water loss and level of coughing will displayed in decibels (dB). Blynk application also used to provide GUI for the ease of user to interpret the measurement data and it will give notification when the measurement is exceeding the desired threshold.

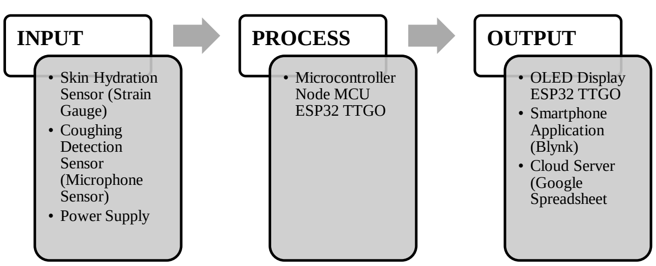


***Fig.1**: Block Diagram of Project Development*

2.2 Flowchart

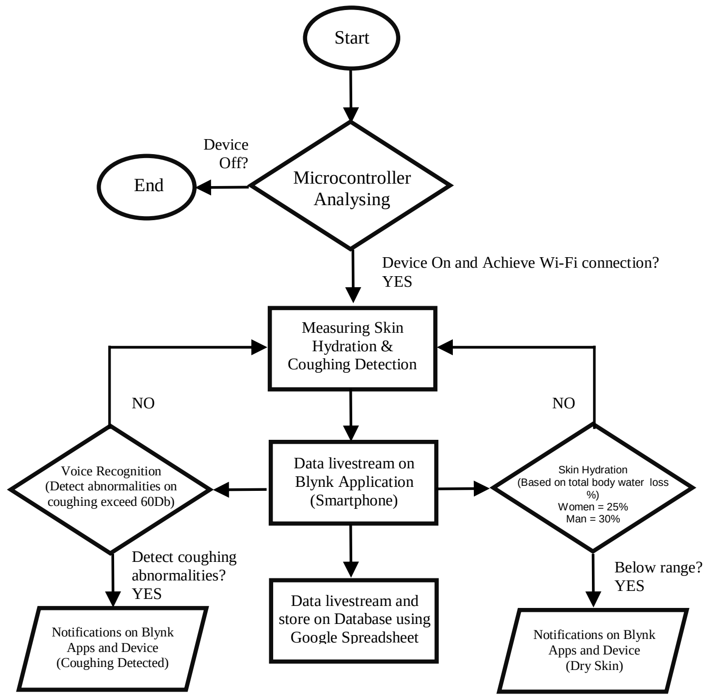


***Fig.2**: Operational Flowchart of Project Development*

Based on flowchart shown in figure 3-3, by power on the microcontroller unit ESP32 TTGO Node MCU, the processor begins to analyze the connections to connect on the Blynk Application on smartphone using Wi-Fi hotspot. For the skin hydration parameter, the program will continue measuring the skin impedance by showing body water loss on percentage (%). If there is no touch between the strain sensor and the skin, the output reading will be 0%. There are differences between man and women measuring program set, woman is set on 25% water loss while man is set on 30% water loss. For coughing detection, the measuring application is based on decibels (dB) of coughing. The program is set for bad coughing above 60dB will notify on the device and application. Both input sensor will continuously be measuring the parameter and all the measurement data will be livestream to Blynk Applications and Google Spreadsheets Database. The database will store the measuring data every 25ms. If one of the sensor are detecting abnormalities on measuring the data set, the device and Blynk Application will notify the end user with pop-out notifications.

2.3 Development of Measurement Circuit

Figure 3 shows the circuit construction for the project development. Table 1 shows the connection of ESP32 TTGO Node MCU pins with component. Slide switch is used as power button connected between the battery and microcontroller board. The construction need to be as minimal because it is a wearable device and it must be very handy and light.

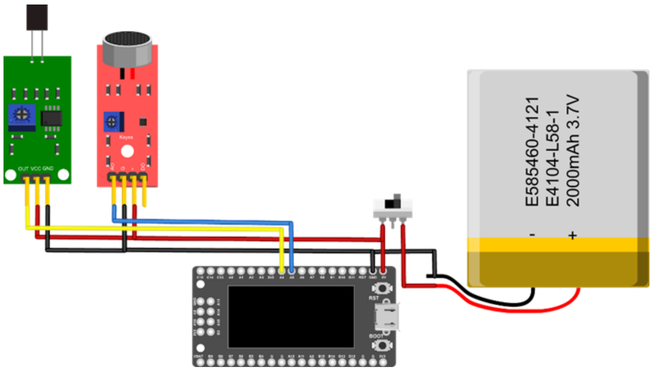


***Fig.3**: Measurement Circuit*

***Table 1**: Pins Connection Detailed*

No.	ESP32 TTGO Pins	Sensor Pins
1.	Pin 32	OUT Strain Gauge Sensor
2.	Pin 33	A0 Sound Sensor Module
3.	GND	GND for both sensor
4.	5V	Supply for circuit

2.4 Development of E-Pilgrims Application

Blynk is used to develop the smartphone applications in this project. Blynk is known as open source IoT platform is a hardware-agnostic platform with white-label mobile apps, private clouds, device management, data analytics, and machine learning. In this project development prototype, the interface on smartphone application consists of several customize widget based on output parameter need to show for the GUI.

Labeled Value is used to displays incoming data from both sensors or any virtual pins set on the programming and it has a formatting string. For this project application, output for hydration level is percentage level and for coughing level is decibels (dB). Super Chart to visualize graphical or historical data live. This widget supports up to 4 data streams at single time. The data measure from the hardware with desired using timers. Gauge is for display incoming numeric values. Can work in 2 modes either Push mode or Reading mode. On this develop, Push mode are being used. In this mode, every data that hardware sends to the server is stored automatically on server. The code used for both parameter is:

```
Blynk.virtualWrite(V0, percentage);
Blynk.virtualWrite(V2, newdB);
```

Notification allow push notification from hardware to the application. In this development, the program has been set to notify when the data is exceeding the level of measurement desired and notify whether the hardware is connecting (online/offline) with the application. The code used for this settings is

```
Blynk.notify("WARNING! Dry skin!");
Blynk.notify("WARNING! Cough detected!");
```

Web Hook is a widget design specifically for third party integrations requests to any server or device. This widget usually uses in a case when the hardware to send data not only to Blynk, but also to another server such as Thingspeak, Google Script, and any other cloud storage server available. On this development, Google Script have been used to display data livestream and store the data in a spreadsheet as a database

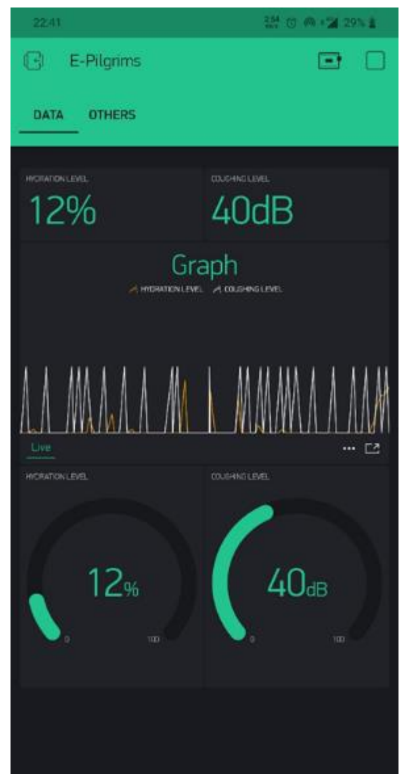
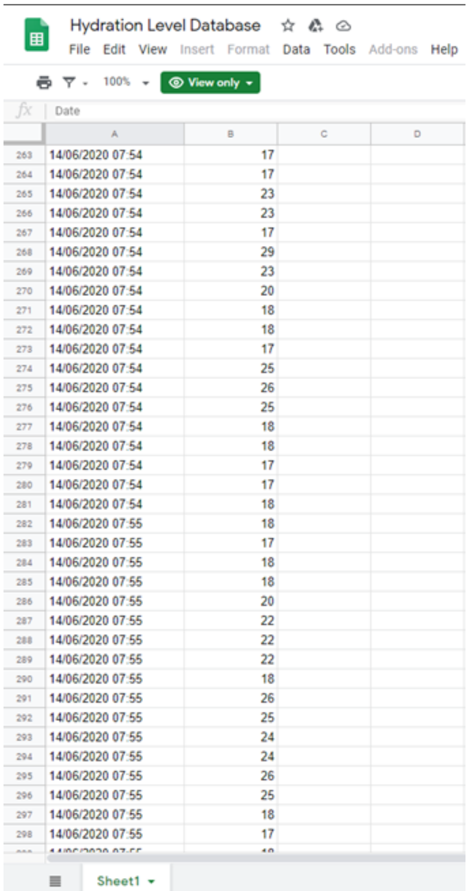


Fig.4: Development of Blynk Application GUI

For database of the measurement data, this development of project is using Google Apps Script. It is a scripting platform developed by Google for light-weight application development in the G Suite platform. It is a cloud based debugger for debugging App Scripts in the web browser. On this development, Google Spreadsheet is used to store the data measurement from the device. The program has been set every 25ms will read new measurement.



	A	B	C	D
263	14/06/2020 07:54	17		
264	14/06/2020 07:54	17		
265	14/06/2020 07:54	23		
266	14/06/2020 07:54	23		
267	14/06/2020 07:54	17		
268	14/06/2020 07:54	29		
269	14/06/2020 07:54	23		
270	14/06/2020 07:54	20		
271	14/06/2020 07:54	18		
272	14/06/2020 07:54	18		
273	14/06/2020 07:54	17		
274	14/06/2020 07:54	25		
275	14/06/2020 07:54	26		
276	14/06/2020 07:54	25		
277	14/06/2020 07:54	18		
278	14/06/2020 07:54	18		
279	14/06/2020 07:54	17		
280	14/06/2020 07:54	17		
281	14/06/2020 07:54	18		
282	14/06/2020 07:55	18		
283	14/06/2020 07:55	17		
284	14/06/2020 07:55	18		
285	14/06/2020 07:55	18		
286	14/06/2020 07:55	20		
287	14/06/2020 07:55	22		
288	14/06/2020 07:55	22		
289	14/06/2020 07:55	22		
290	14/06/2020 07:55	18		
291	14/06/2020 07:55	26		
292	14/06/2020 07:55	25		
293	14/06/2020 07:55	24		
294	14/06/2020 07:55	24		
295	14/06/2020 07:55	26		
296	14/06/2020 07:55	25		
297	14/06/2020 07:55	18		
298	14/06/2020 07:55	17		

***Fig. 5**: Google Spreadsheet as database using Google Apps Script*

3.0 RESULTS AND DISCUSSION

3.1 Current Draw of Sensing Module

Current draw is measured on this project development to prevent spending too much on a power supply (batteries on higher voltage). It is measure to achieve battery optimization of the load base. The ESP32 TTGO Node MCU is connected with Blynk and sensor at a time to calculate the current drawn by the board. Table 2 shown current drawn consume by each circuit. On the observation the total current drawn is about out to be 100mA. A 900mAH battery can run on current prototype development about ±9 hours depends on usage. To further reduce the current consumption, the program can be set to read data from sensors after some regular intervals and then connect through Blynk application to transmit the data.

$$Run\ Time\ in\ Hours = \frac{Battery\ Pack\ Capacity\ (mAh)}{Project\ Currrent\ Consumption\ (mA)}$$

$$\frac{9000mAh}{0.97mA} = 9.278350515 \text{ hours}$$

***Table 2**: Current draw consume by each circuit*

Component	Current Draw
ESP32 TTGO (Disconnect with Blynk without sensor)	18 mA
ESP32 TTGO (Connected with Blynk without sensor)	37 mA
ESP32 TTGO + Strain Gauge + Mic Sensor (Connected both sensor with Blynk)	97 mA

Battery with a capacity of 9000mAh and a project consuming 97mA has a runtime of about 92.78350515 hours. For reminder, this calculation based on theory only and maybe it is not precise in anyway and the calculation will give approximate value only. Environmental factors like temperature have a big impact on the actual run time. Another factor is the quality of the power cells used battery supply. All battery supply will start to discharge quicker as it loses charge, some might also have voltage drop.

3.2 Hydration Level Measurement

For hydration measurement data analysis, two persons are involved in data collection. Details of persons can be obtained on a table 4-3 below. Several condition are being set up based on Mecca whether and environment to simulate the situation during Hajj and Umrah occasion throughout the year. Skin hydration measurement level are set to measure the percentage (%) of water loss in human body. In this development, percentage of water loss are different between man and woman because of gender and physical factor. For man, percentage water loss is set to 30% and for woman is set to 25%. The sensor is place on to the right hand of subject wrist by attached the sensor using tape.

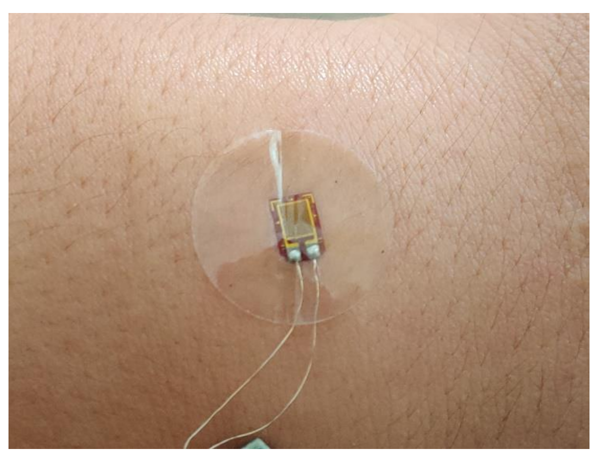


***Fig. 6:** Sensor Attached on Subject Wrist*

***Table 3**: Data collection on skin hydration based on condition*

Environment	Skin Condition	Man		Woman	
		Hydration Loss (%)	Voltage (mV)	Hydration Loss (%)	Voltage (mV)
Outdoor					
Hot Weather (35°C - 40°C)	Without Lotion	21%	1132	18%	1121
	Lotion Applied	12%	1008	10%	959
Cloudy (30°C - 35°C)	Without Lotion	9%	935	9%	932
	Lotion Applied	0%	848	0%	849
Raining (25°C - 30°C)	Without Lotion	0%	847	0%	848
	Lotion Applied	0%	850	0%	850
Indoor					
Hot Room Temp.	Without Lotion	17%	1119	13%	1011
	Lotion Applied	10%	960	5%	864
Normal Room Temp.	Without Lotion	8%	927	1%	858
	Lotion Applied	0%	850	0%	847
Cold Room Temp.	Without Lotion	0%	850	0%	849
	Lotion Applied	0%	849	0%	850

Table 3 shown the series of measurement taken of skin hydration based on environment. The experiment is divided into two which is indoor and outdoor. Both are being tested on three different temperature environment to simulate the weather in Mecca. The measurement shows when the temperature of environment is high, the hydration percentage loss also increases. The voltage measurement parallel with the percentage of hydration loss. The experiment continues by applying lotion moisturizer on skin surface. The percentage differences are quite large compare skin without lotion. Tiny size of strain gauge would be the factor that the reading is not that precise because it only measure on a tiny surface area of a skin only.

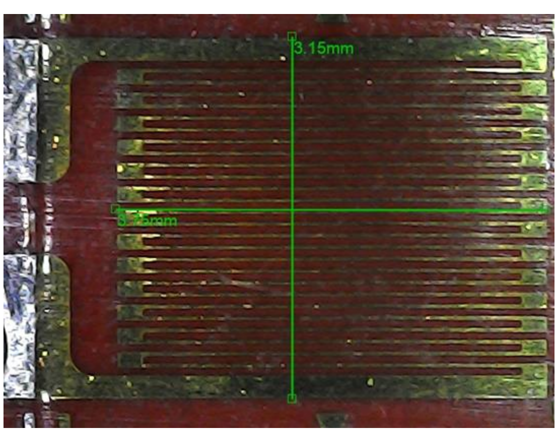


***Fig. 7:** Strain Gauge Used in Development of Project Size*

3.3 Coughing Detection Measurement

The implementation of analysis on Coughing Detection is the same as Hydration Level Measurement by using two subjects to obtain the data. The subjects are man and woman age 62 years old and 58 years old. Several conditions are being simulate to measure the differences between environment and level of health. The sensor is set to 40dB as it starting point of measurement and the sensor is placed in front of the face about 0.3-meter distance. Sound meter application in smartphone is used to differentiate the reading measurement between the device and sound meter. All data shown in table 4 are the measurement result.

***Table 4**: Data collection between sound meter and development device in decibels (dB)*

Condition	Sound Meter (dB)		Development Device (dB)	
	Man	Woman	Man	Woman
Not Fasting in Hot Weather	68	55	60	51
Not Fasting in Normal Weather	58	51	56	50
Not Fasting in Cold Weather	55	49	56	48
Fasting in Hot Weather	73	60	70	59
Fasting in Normal Weather	69	59	70	57
Fasting in Cold Weather	69	57	70	57

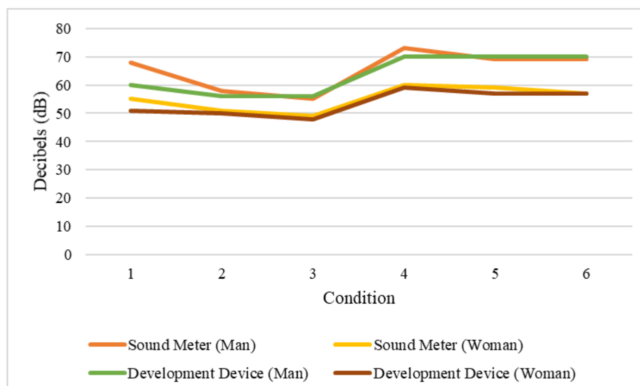


***Fig. 7**: Graph trend on coughing detection measurement*

5.0 CONCLUSION

This development project presents of existing health and behavior-monitoring approaches based on wearable IoT technologies. IoT implementation in Medical Healthcare practice especially in remote health monitoring would be beneficial for both party consumer and provider. This development also illustrate interestingly new health monitoring system based on Web Information System Engineering (WISE) which enable real time monitoring of the pilgrims. The uniqueness of this project from the fact this approach toward the wearable device technology in measurement skin hydration and coughing level detection have never been widely explored and implemented in any marketable wearable device. The sensor specifically for both parameters itself never been develop on market usage. This development prototype would be beneficial to other industry not only on pilgrim usage during Hajj and Umrah occasion. In additional it can be used on sports industry to track athlete hydration level during sport and training

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