Health Monitoring System Using IoT Devices for the Pre-Assessment of Common Elderly Respiratory Diseases

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***Abstract*— With the increasing population of the elderly people, remote health monitoring systems become more efficient and popular. Integrating Internet of Things (IoT) in these systems have been progressing in the past years providing daily monitoring as well as prompt medical action for early prevention of diseases. In this study, the proponents proposed a health monitoring system using IoT devices for the pre-assessment of the common elderly respiratory diseases called Rescue-Wear. The system measures vital signs such as heart rate, blood oxygen level, body temperature and respiratory rate as well as the symptoms that the elderly experiences. Arduino Nano microcontroller was used to collect data from the sensors and then forwards it to the Raspberry Pi 3 to process all the data collected. The system will provide a text message notification through Sim800c GSM. An android application is also developed with this system so that users can update their information and to display the history logs of all tests conducted in the device. Through Random Forest Classification Algorithm, the system was able to provide a prediction model for the pre-assessment result based on the overall data collected by the system with an accuracy of 96.97% for Pneumonia and Bronchial Asthma and 87.88% for URTI.**

***Keywords*— (Health Monitoring, Internet of Things, Respiratory Diseases, Vital Signs, Classification Algorithm, Random Forest)**

I. Introduction

As of 2015, the Philippines population aged 60 years old and above totaled to 7.5 million which is equivalent to 7.5 percent of the total population in the country. Currently, Philippines ranks second among Southeast Asian countries with a high annual growth rate and by 2100, the population of elderly people was forecasted to reach up to 25.6 percent [1]. According to the Department of Health, the leading causes of morbidity in the country were respiratory diseases including Acute Respiratory Infection, Bronchitis, and Pneumonia [2].

As people age, their immune system weakens, making them vulnerable to illnesses. This makes the elderly people more likely to suffer chronic diseases or to have a pulmonary disease. One of the biggest challenges in the present is accessing medical facilities like hospitals, clinics, and health centers. In hospitals, the ratio of nurses and doctors compared to the patients are low. There is also travel restrictions for ages above 65 years old so there is a struggle when it comes to providing healthcare support and assistance. Also, to be able to produce a diagnosis out of obvious circumstances, one must run a test first before acquiring data, that can result to life and death situation to the elderly patient. As a result, they cannot go to hospitals regularly and, hospital cost increases. On the other hand, frequently, worsen health condition and critical state can be results of disregarding to measure the vital signs of the elderly like their heart rate, blood oxygen level and body temperature. To resolve this, a real-time health monitoring system for the elderly should be established.

Health monitoring systems (HMS) aid with an elderly's basic healthcare essentials. HMS requires data acquisition from various parameters to evaluate the person's health conditions. The system can monitor and assess the health state of the elderly subject, provided that the system is made for a specific health concern. It aims to reduce cost and provide timely health services for elderly people who wishes to maintain their independence [3].

Internet of Things (IoT), a progressive paradigm in linking physical and virtual things for heightened services using internet, was introduced to deliver substantial advances in remote health monitoring. It is an advance technology implementing sensor development, data collection, communication, and networking, managing of data and data processing, where things can connect to a remote server and also to form local networks. Exchanging and merging of data to attain extensive knowledge in regards with their functionality along with the environment are some of the features of IoT-based systems. Through cloud computing, IoT can generate different amount of information and can be used to reduce human effort and easy access to physical devices [4].

Classification algorithm is a Supervised Learning Technique used to identify the category of new observations based on training data. In Classification, datasets were used in a program to classify new observation into several classes or groups [5]. It is the method of finding a set of models that describe and separate data classes or concepts for the intention of predicting the class of object whose class label is unknown. Classification is important for management of decision making [6]. Several classification algorithms are considered in this system such as Logistic Regression, Naïve Bayes, Random Forest, and Support Vector Machine (SVM).

Based on the discussion, home-based health monitoring system is one of the best solutions to enable remote monitoring of the health conditions of the elderly as well as early predictions of the commonly acquired respiratory diseases. The proposed system introduces a portable and accurate health monitoring system dedicated for the elderly people that can be used to monitor their vital signs such as heart rate, blood oxygen level, body temperature, and respiratory rate using biomedical sensors and microcontrollers such as Arduino Nano and Raspberry Pi 3. The hardware system will be accompanied by an Android Application to act as the gateway to have access and it will display the generated results from the device and users can manage their information through the application. The collected health parameters and the trained data from the classification algorithm are processed in the system to generate the overall pre-assessment result of the elderly.

II. RELATED WORK

An IoT Health Monitoring System is a group of Internet of Things (IoT) devices integrated to provide health-related information for better surveillance over a patient [7]. It may come in various forms, depending on the prior diagnosis of the patient to be observed e.g. the elderly. Medical practitioners have access to the data through a notification system. Continuous health monitoring is vital to ensure the elderly person's well-being.

IoT-based healthcare systems depend on the definition of IoT as a network of wearable devices, connected to each other to measure the parameters, read results, and make alert systems to inform the person involved either family member or medical personnel. These healthcare systems are intended to get immediate measurements essential in tracking down some health parameters in crucial situations in a cost-effective way. Sensor mobile gateway combined with biosensors can preferably presented on small, portable devices such as smartphones and personal digital assistant, the reason on how IoT-based health systems can reduce the cost while improving the health by increasing the availability and quality of care [8].

The study proposed by [6] developed an IoT-based patient monitoring and diagnostic prediction tool using ensemble classifier. The established system was used to monitor the health conditions of stroke patients. To provide diagnostic predictions, the combination of IoT-based monitoring and machine learning prediction techniques are implemented. Classification algorithms are utilized for the diagnosis and prediction. Constantly checking the health parameters of the patients was possible through the improvement of the sensors and Internet of Things. The sensors are used to collect the health parameters of the patients and forwarded to cloud for storage. The gathered data are analyzed to determine if any abnormalities are present. The cloud server is responsible for storing and analyzing data and will generate alert messages if there is any change in the value. The data can be viewed through a web application by the doctors.

A watch-over system for elderly people living independently and those who are left at home was implemented by [9]. To implement IoT technology, the proponents used Raspberry Pi IoT device with motion sensors, and temperature sensors that are situated inside the elderly's home. The system sends direct messages in Line application for the concerned family members whenever an elderly was seen to have an unhealthy state. The system has two modes, an idling mode and watch over mode. Family members are provided with a beacon connected to the Raspberry Pi so that the system will know who is already present in the house. The system divided the information that will be sent in Line with emergency and non-emergency messages.

A real-time vital sign monitoring system for elderly, sub-health crowd, and insomnia people groups was developed to monitor their sleep quality and heart rate changes. The system uses the vital sign monitoring devices to detect the body's vital signs for a period which mainly includes the heart rate, breathing rate, and state of the bed. Through Wi-Fi connection, the system can transfer the collected data to a cloud platform. The cloud platform analyzes and calculate the vital signs data and the dynamic change of vital signs. Through the cloud platform, cautionary notifications were sent according to the analysis of the vital signs continuous data [10].

III. PROPOSED SYSTEM

Most of the elderly people prefer to stay at home instead of admitting to hospitals due to various reasons like expensive hospital bills, distant health facilities and travel restrictions. Advancement in remote health monitoring helps to constantly monitor their health conditions and early prevention of diseases. The development of a health monitoring system with a wearable platform that can instantly acquire the vitals of an elderly will not only drastically increase the surveillance over the person, but also give them more comfort compared to the usual monitoring apparatus. This work proposes a health monitoring system using IoT devices for the pre-assessment of the common elderly respiratory diseases. These diseases include Bronchial Asthma, Pneumonia and Upper Respiratory Tract Infection that can lead to more complicated illness. The system is composed of software and hardware components. An Android Application was developed for the purpose of gathering the general information about the elderly and acts as the gateway to have access to the hardware system. It displays and stores the generated results from the hardware device and users can manage their information through the application. For the hardware system, it consists of a wearable device that is attached to the elderly person that collects the vital signs like heart rate, blood oxygen level, body temperature, and respiratory rate. The wearable device is then connected to the monitoring device where data is being analyzed to provide a pre-assessment through Random Forest Classification Algorithm. Using Random Forest Classification Algorithm, the system was able to provide the probability of respiratory diseases on an elderly. The collected health parameters and the trained data from the classification algorithm are processed in the system to generate the overall pre-assessment result of the elderly. The system will then send a notification message through Sim800c GSM.

A. *Hardware System*

Fig.1. shows the System Architecture of the health monitoring where the hardware part of the system is divided into two systems. Health parameters like heart rate, blood oxygen level, body temperature and respiratory rate are collected through the wearable device having the Arduino Nano as its main microcontroller. The monitoring device will be responsible for controlling the whole system. Raspberry Pi3 was used as the main computer of the system which oversees analyzing data and transmitting data to the cloud storage.

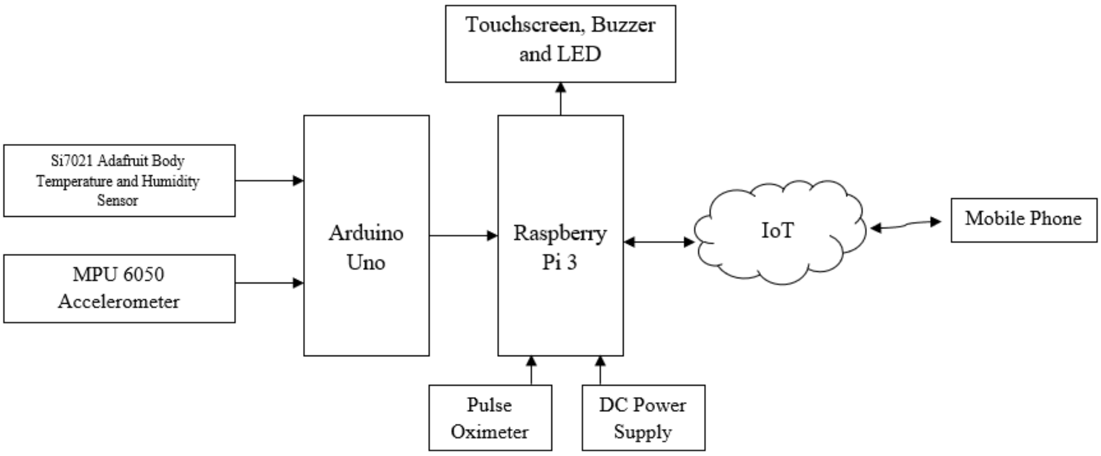

Fig.1 Health Monitoring System Architecture Diagram

B. Wearable Device

Wearable health devices (WHD) are an increasing technology in assisting people to monitor health status for self-health tracking, providing data that can be used for early diagnosis and treatment. WHD focus on acquiring vital signs with a purpose of raising the awareness of the user of managing its own health.

1) Microcontroller: Arduino Nano is the main controller of the wearable device. It is an open-source physical computing platform. It collects all the data from the sensors and forwards it to the Raspberry Pi3.

2) Temperature and Humidity Sensor: The system used Si7021 Adafruit Temperature and Humidity sensor to measure the body temperature. It uses I2C for data transfer so that works with a wide range of microcontrollers.

3) Accelerometer: MPU6050 Gyroscope Accelerometer is a 6-axis Motion Tracking Device. This sensor was used to measure the respiratory rate based on the person's breathing for a minute.

4) Pulse Oximeter: Pulse oximeters are used to measure the heart rate and blood oxygen level painlessly. Oximeters report blood oxygen level via an oxygen saturation measurement called peripheral capillary oxygen saturation, or SpO2.

Fig.2 Assembled Wearable Device

C. Monitoring Device

The system's monitoring device acts as the main computer of the system. It displays the GUI where users can log in to their accounts shown in Fig 3.a-c and start using the services of the system. It is mainly composed of Raspberry Pi 3, a 3.5 touchscreen display and on-site alarm system. To use the device, internet connection is necessary. The device can be connected to the internet through Wi-Fi connection. The system requires a micro-USB power connector and can be powered by a 5.1v, 2A input supply. A respective questionnaire for the symptoms experience by the elderly is also collected to increase the prediction of respiratory diseases. After collecting the vital signs and answering the questionnaire, the system will produce the overall assessment of the elderly. An alarm system is prepared for results with abnormal readings to alert the user.

Fig.3 a-c. Monitoring Device User Interface

Fig.4 Fully Assembled System

D. Software System

The Android Application was developed to accompany the hardware system. It is developed for the purpose of storing elderly's record of tests from the device. Users must sign up first in the application to have access in the hardware system. It requires the general information of the elderly such as their name, age, birthday, weight, height, etc. After every test, an SMS is sent to the registered number to inform the guardian about the results conducted on the device.

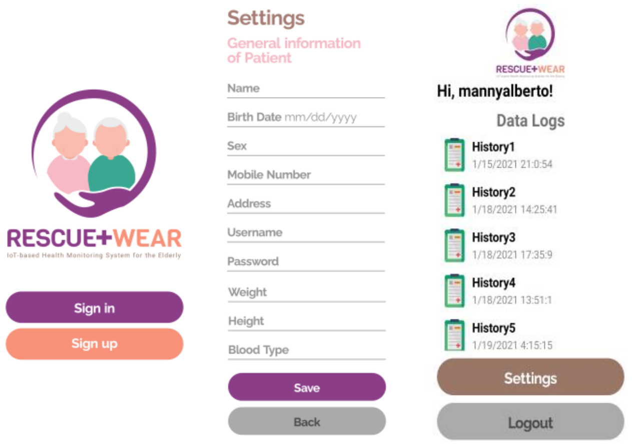

Fig.5 (a) Sign Up/In Screen, (b) Input of General Information for Sign Up, (c) Application Dashboard

E. Algorithm Design

Classification algorithm is used to predict the probability of a respiratory disease in the elderly. Different classification algorithms were considered such as Naïve Bayes, Logistic Regression, Random Forest and Support Vector Machine. The performance of these algorithms was compared, and Random Forest Classification Algorithm showed the highest accuracy, thus, applied in the system.

1) Random Forest Classification Algorithm: It is a predominantly ensemble learning method of unpruned classification trees for classification and regression. In prediction, random forest utilizes multiple decision trees and provides outstanding performance on several practical problems, for instance healthcare prediction problems as it is not sensitive to noise in the dataset and is not subjected to overfitting.

F. System Flowchart

Figure 7. illustrates the flowchart of the system. The wearable device must be plugged in the USB port of the monitoring device to power the Arduino Nano microcontroller and gather the vital signs using the sensors. By powering the system with a power adapter or power bank with an output of 5.1 v 2A, users will then be able to operate the system. Wearable device must be put on the lower chest area or in the diaphragm. Users must have an account first before they can use the system otherwise, they must sign up in the application and input the necessary information. Collection of vital signs is done after selecting the "Check Vitals" option. After one minute of measurement, "Recheck Vitals" will appear, and users will select if they want to repeat the process or not. If the users choose not to recheck the vitals, they must answer the questionnaire regarding the related symptoms and conditions with the three respiratory diseases included in this study. After the collection of the necessary data, the system will generate the pre-assessment result which includes the vital sign measurement, the probability of the respiratory diseases and the answers to the previous questionnaire. If the result showed a high probability of a respiratory disease, the system would alert the user using red LED and buzzer. After conducting test, a notification SMS will be sent to the registered number in the application to inform the guardian about the results of the test. Guardians can also view the elderly's record through the mobile application.

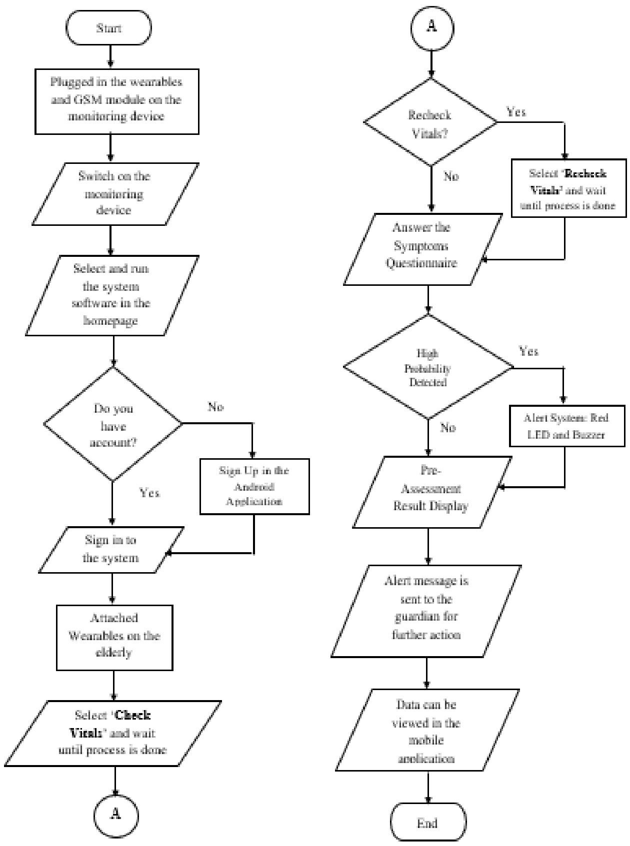

Fig.7 System Flowchart

IV. RESULT AND ANALYSIS

A. Dataset

For the prediction system, dataset was used that consists of 240 records of patients which contains details of affected and unaffected elderly by a respiratory disease. Each disease has a corresponding dataset that varies depending on the condition of the elderly. It contains attributes like age, gender, and the symptoms experience by the patient.

B. Analysis of Classification Algorithm

Various classification algorithms are analyzed for the prediction model and the algorithm which gives the best accuracy is considered in the system. These include Logistic

Regression, Naïve Bayes, Random Forest Classifier and Support Vector Machine. The performance of each classification algorithm was evaluated by training and running the dataset in the program to prove what algorithm gives the best prediction result. Fig.7 depicts analysis graph among these algorithms and Random Forest Classifier showed the highest accuracy with a result of 96.97% for Bronchial Asthma and Pneumonia and 87.88% for Upper Respiratory Tract Infection (URTI).

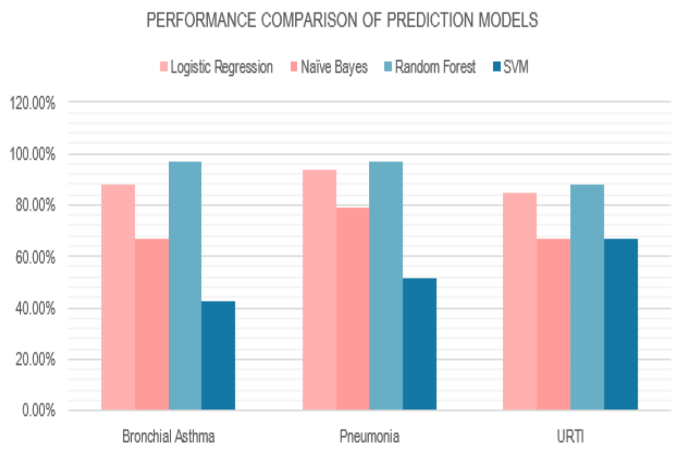

Fig 8. Accuracy Comparison Chart of Classification Algorithms

C. Functionality Testing

The performance of the health monitoring system designed in this paper is validated through series of tests conducted in this device. Seven senior citizens agreed to be monitored using the system. Together with their guardian, they were oriented about how the system works and the benefits in daily monitoring of vital signs. The system output consists of measurement of vital signs, probability of respiratory diseases, and summary of answers from the questionnaire. Fig.9 to Fig.10 shows the output from the monitoring device while Fig. 11 shows the output from the Android application. Fig.11(a-b) shows the alert message sent to the registered number in the Android Application. This informs the guardian about the results of the test conducted.

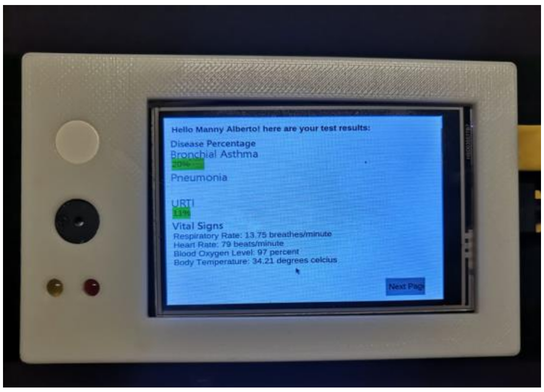

Fig 9. Vital Sign and Probability Assessment

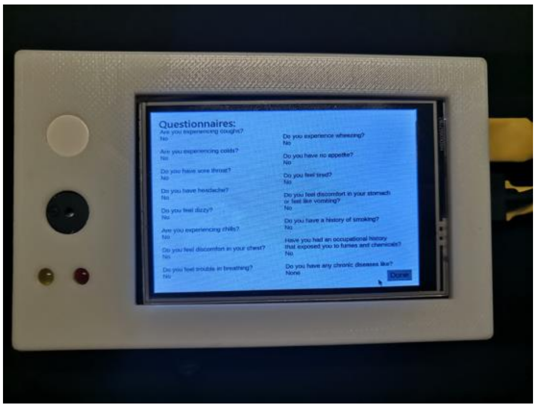

Fig.10 Summary of the Questionnaire

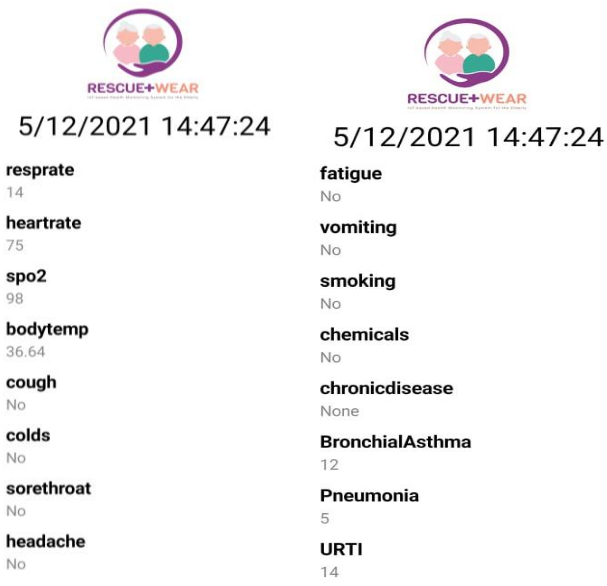

Fig.10 (a-b) Assessment Result in Android Application

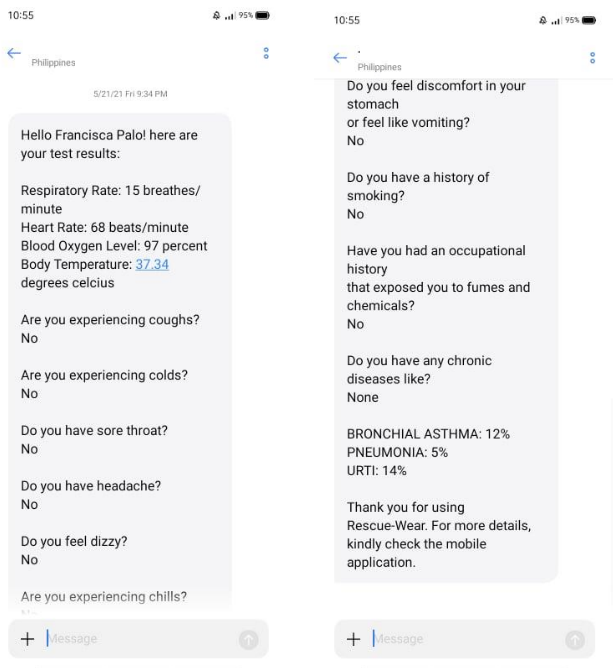

Fig.11 (a-b) Alert Message for Guardian

D. Sensor Accuracy Testing

There are three vital signs accuracy measurement conducted which are heart rate, blood oxygen level, and body temperature. Parallel testing between the Rescue-Wear System and commercially available devices was conducted to test the accuracy of the device. For each vital sign measurement, few testing data have been measured and the average accuracy was calculated. Fifteen results were compared to each other. Figure 12-14 shows the result of the comparison.

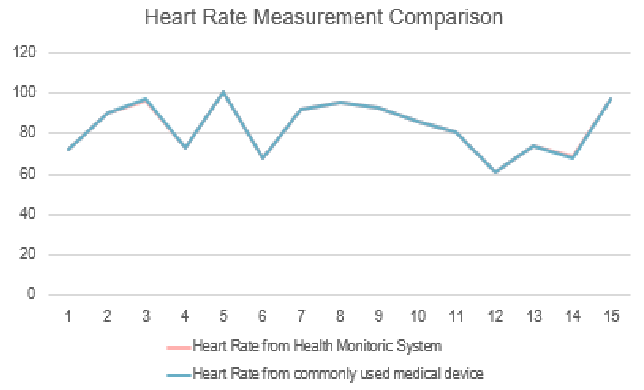

Fig.12 Heart Rate Comparison Graph

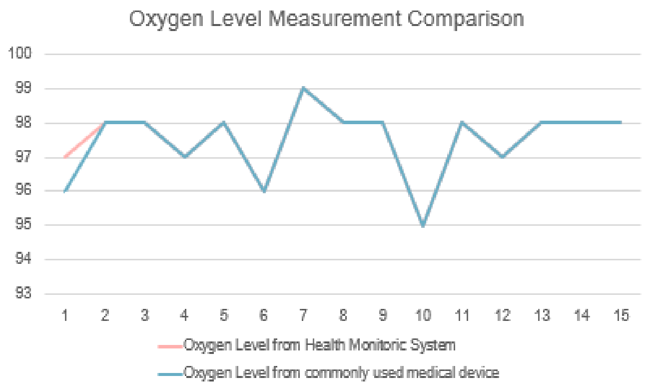

Fig.13 Blood Oxygen Level Comparison Graph

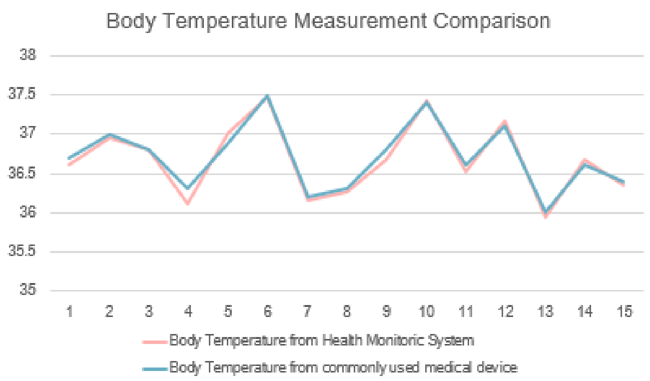

Fig.14. Body Temperature Comparison Graph

By using accuracy mathematical formula as shown in (1), the overall accuracy of vital sign measurement of Rescue-Wear is calculated and summarized in Table I.

$$Accuracy\ (\%) = \frac{|(Experimental\ Value - Accepted\ Value)|}{Accepted\ Value} \times 100\% \quad (1)$$

TABLE I. TABLE OF VITAL SIGN ACCURACY

Vital Signs	Accuracy
Heart Rate	99.83%
Oxygen Level	99.93%
Body Temperature	99.81%

The device showed high accuracy results based on the comparison test conducted. Body temperature has a slightly lower compared to the two vital signs because of the outside factors that can affect the system like the weather.

V. CONCLUSION

This paper has presented a portable and high accuracy health monitoring system using IoT devices for the pre-assessment of common elderly respiratory diseases. The system can measure vital signs like heart rate, blood oxygen level, body temperature and respiratory rate based on embedded Arduino Nano and Raspberry Pi3 microcontrollers. Based on the results of the study, the Rescue-Wear System can successfully provide an overall pre-assessment result of the commonly acquired respiratory diseases of the elderly based on the health parameters gathered. It offers benefits such as:

- Improves regular monitoring of vital signs through the wearable device to decrease the morbidity rate of the elderly.
- Delivers accurate vital signs reading through biomedical sensors.
- Provides the probability rate for early detection of respiratory diseases.
- Accessible through mobile application to modify information and access data records.
- It offers home-based monitoring perfect for elderly people who have difficulty in traveling and accessing hospitals.

VI. FUTURE WORKS

In the future, further improvement of the design is encouraged to make the device more compact and portable. A notification for the android application must also be implemented to extend the notification service of the system. Other than that, it is highly recommended to gather a higher number of datasets that will be used for the prediction model to increase the accuracy of the prediction. Another concept for future work is to improve the system for a wider range of users and to assess other illnesses like cardiovascular diseases.

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