Home-Based Health Monitoring System Utilizing Internet of Things and Random Forest Classifier for Common Respiratory Diseases of Elderly People

Christian Lenard E. Buenavidez, Kayle Mae Familaran, Frances Virgie P. Look, Jeremias Francisco A. Roman III, Ramon Alfonso G. Uy, Cherry G. Pascion, Jay Fel C. Quijano, Timothy M. Amado, Romeo Jorda Jr.
Technological University of the Philippines
Email: christianlenard.buenvidez@tup.edu.ph, kaylemae.familaran@tup.edu.ph, francesvirgie.look@tup.edu.ph, jermiasfrancisco.romaniii@tup.edu.ph, ramonalfonso.uy@tup.edu.ph, cherry_pascion@tup.edu.ph, jayfel_quijano@tup.edu.ph, timothy_amado@tup.edu.ph, romeo_jorda@tup.edu.ph

Abstract – A rapid rise with the elderly population in the country calls for more health and medical support. Home-based health monitoring systems are gaining more attention in the past years as a lot of people opt to have a means of medical support even at the comfort of their home. Having elderly people more prone to diseases means that they will always need special attention in terms of observing their health and monitoring how it progress every day. This paper proposed a home-based health monitoring system with the use of Internet of Things and Random Forest Algorithm that aims to pre-assess the common respiratory diseases acquired by the elderly people. It involves portable hardware system composed of Arduino Nano and other biomedical sensors that measures their heart rate, blood oxygen level, respiratory rate and temperature. With the help of Internet of Things, data are stored in a cloud-based system and can be accessed through a mobile app. Through Random Forest Classifier, the system was able to develop a prediction model of 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

The internet of things and its related technologies have been playing a significant role ever since it was developed in many applications such as in agriculture, business, and medical field. One of the visions of IoT is that things can be easily controlled and monitored, can communicate over internet, and can make decisions by themselves [1]. The innovation of Internet of Things in medical field amplified the effectiveness of remote health monitoring of patients and elderly people who needs special attention of long-term personal care. Advanced health monitoring systems allowed doctors to virtually view the patient's conditions and information by using smart medical applications installed in their laptops or mobile phones [2]. As health is one of the most significant factors in life, remote health monitoring had become one of the most popular advances in the technology and a lot of individuals have been relying on and purchasing portable devices to keep track of their medical conditions.

Philippines, being one of the countries with a growing rate of elderly people that is 7.5 percent of the overall population as of 2015, is rated second among the Southeast Asian countries [3]. Female seniors have the numeric advantage constituting to 60% of the total elderly population with an average lifespan of 70 years old. Male seniors on the other hand registering to an average of 69 years. A larger number of elderly people choose to utilized outpatient rather than inpatient care that is reportedly 4 out of 10 patients. While there are many reasons for not seeking help at that time, the most common one is the lack of financial means which is an indicative of unmet need of medical attention [4]. Based on the Department of Health, one of the leading causes of morbidity in the country are respiratory diseases such as Acute Respiratory Infection, Bronchitis, and Pneumonia. Philippines has a high rate of smokers among the elderly people making them more vulnerable to respiratory diseases [5].

Health monitoring systems and Telemedicine are both advance uptakes to provide a clinical healthcare at a distance. Utilizing wearable and wireless sensor-based systems to gather medical data and deliver care directly to patients are widely used. This is possible through the biomedical sensors that can be used to capture vital signs like heart rate, body temperature, blood oxygen level, and respiratory rate. There are also ones that can be used to measure blood pressure and glucose level. Systems can be developed based on the needs of a specific medical condition and can provide assessment based on the test data in addition to the actual data gathered. Health monitoring systems aims to reduce the cost of medical services while being able to continually monitor and provide assessments for those people who have difficulties in accessing medical services and facilities [5].

Classification algorithms are commonly used for prediction that collects substantial amount of data to produce a prediction model for decision-making. The goal of classification is to accurately predict a target class for each case in the data [6]. It is a Supervised Learning Technique that finds a set of targets or functions that describe or distinguished data classes or concepts, for the purpose of predicting the class of objects whose class label is unknown. There are many types to classify data including Random Forest Classification, Decision Tree Induction, Neural Networks, Bayesian Network and Support Vector Machines. Random Forest Classification falls under ensemble-based learning methods. The key principle of random forest approach is that it involves the construction of many simple decision trees in the training stage and the majority vote across them in the classification [7].

The proposed study presents a remote health monitoring system focused on the elderly people to gather daily health assessments like their vital signs; heart rate, blood oxygen level, respiratory rate and body temperature using biomedical sensors while utilizing Internet of Things and Random Forest Classifier. Arduino Nano and Raspberry Pi 3 were used as the microcontrollers of the system. Together with the hardware system, applying Internet of Things made the development of an Android application possible to have daily logs of the health assessment gathered by the hardware system. The application is encrypted for data security. 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. METHODOLOGY

A. *Theoretical Framework*

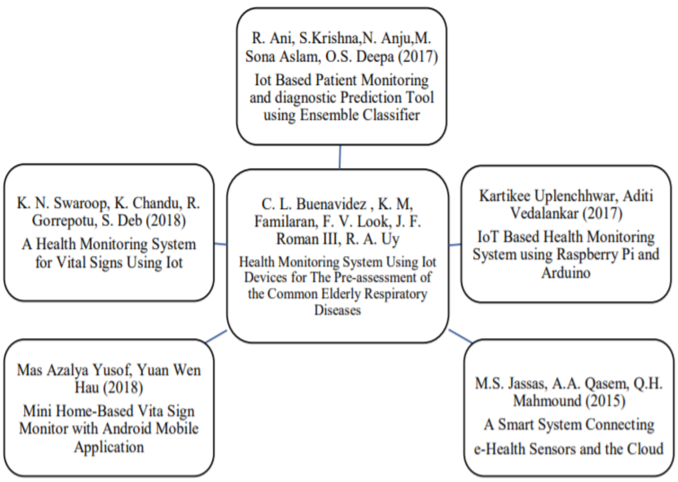

Figure 1. Literatures Closely Related to the Present Study Under Investigation.

Figure 1 which shows the theoretical framework of the study consists of the literatures closely related to the study under investigation.

The IoT Based Elderly and Diagnostic System is derived from the previous studies conducted by R. Ani et al. which focused the Monitoring and Diagnostic System of the stroke patients using the various sensors mounted on the microcontroller. Multiplexed and multimode communication was used by K.N. Swaroop et al.`s Health Monitoring System which offered a real-time patient monitoring system for the patient's vital signs which enhances the healthcare delivery by communicating multiplexed data through the mobile application, SMS and the Internet. The hardware set-up of the proposed project is modeled through K. Uplenchhwar et al.`s and M.A. Yusof et al.`s research. Uplenchhwar made use of the Arduino as the microcontroller system while the Raspberry Pi served as the computer for the data transportation to the outputs. Meanwhile, this project will be using the same sensor as what Yusof et al had utilized in their research as a great tool for the detection of the respiratory parameters. The software and diagnosis system are aided through M.S. Jassas et al.`s research which emphasized the use of cloud in the data transmission.

B. *Conceptual Framework*

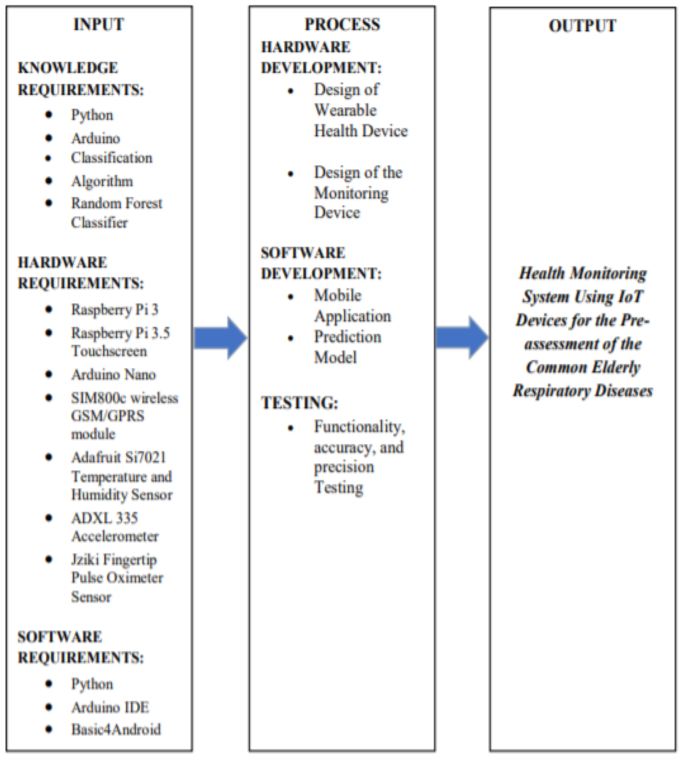

Figure 2. Conceptual Network

The figure shows the main sections of the study that is composed of INPUT – PROCESS – OUTPUT. This study focuses mainly on monitoring the health parameters of the elderly by collecting their vital signs through different biomedical sensors. Real-time data collected over Arduino Nano will then be transferred to Raspberry Pi to be processed as well as the additional data done after answering a questionnaire for symptoms. Random Forest Classifier is used to create a prediction model of these diseases to detect their probability on the elderly. Datasets will be installed in the system to increase the probability and accuracy rate. Tests done through the system will be accessible through an android application to help the guardians in monitoring the health condition of the elderly daily.

C. Research Process Flow

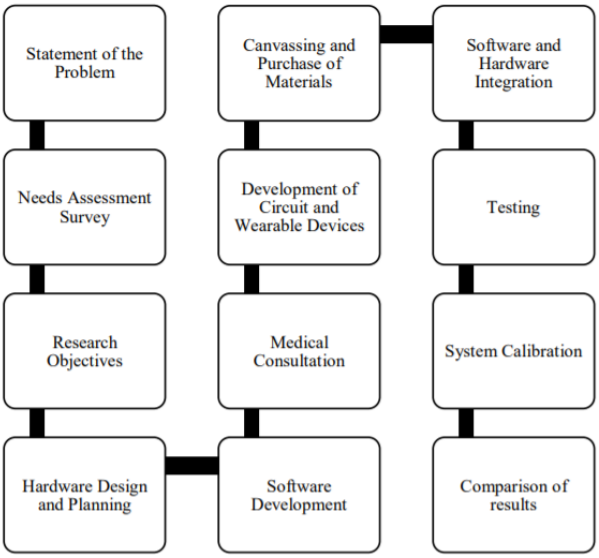

Figure 3. Research Flow Diagram

Figure 3 shows the process flow of the research which will be followed for the completion of the objectives.

D. Block Diagram

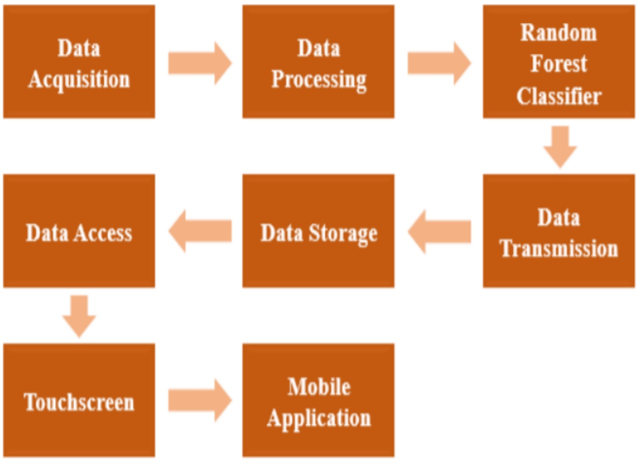

Figure 5. Block diagram of the system

Figure 5 represents the Block Diagram of the System. The sensors installed will be used to collect data such as heart rate, body temperature, humidity, respiratory rate and oxygen level. Arduino Uno will acquire and process data from the sensors. Data will be forwarded to Raspberry Pi 3 to process it as it contains the program for Random Forest Classification Algorithm. Active communication is required for the system to transmit health data for monitoring and alerts. Wi-Fi, Bluetooth, and USB boot capabilities are some of the advantages of the Raspberry Pi for this device. The data will be stored using at the storage. The GSM modem operates over a subscribed mobile operator using a SIM card to send data using SMS. Real-time results will be displayed through the touchscreen monitor and the saved records can be accessed using the android application.

E. Hardware Design

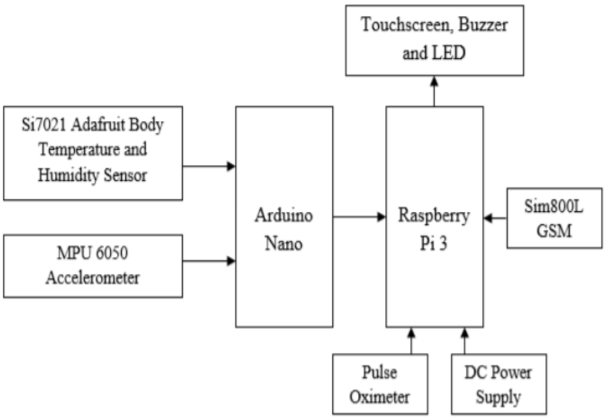

Figure 4. Hardware Block Diagram

The proponents will start by constructing the wearable device using Arduino Nano microcontroller, temperature and humidity sensor, accelerometer, and pulse oximeter. Then, building the monitoring device using Raspberry Pi 3, Raspberry Pi 3.5 in Touchscreen, and the on-site alarm system using LED indicators and buzzer. The chassis of both devices will be fabricated through 3D printing using PLA filament. By connecting Raspberry Pi to the internet, the device will be able to transfer the data from the monitoring device to the android application.

1) Microcontroller: Arduino Nano is the main controller of the wearable device. It collects all the data from the sensors and forwards it to the Raspberry Pi3.

2). Main Computer: Raspberry Pi 3 is a single board computer with wireless LAN and Bluetooth connectivity.

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.

Figure 6. Fully Assembled System

F. Graphical User Interface (GUI)

To provide a more user-friendly set up, the proponents developed a Graphical User Interface that can be navigated easily using Adobe Photoshop. For the hardware system, it shows the Sign in Page, the prompt to check vitals, and results.

Figure 7 a-c. Monitoring Device User Interface

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.

Figure 8. (a) Sign Up/In Screen, (b) Input of General Information for Sign Up, (c) Application Dashboard

G. Flowchart

a. System Flowchart

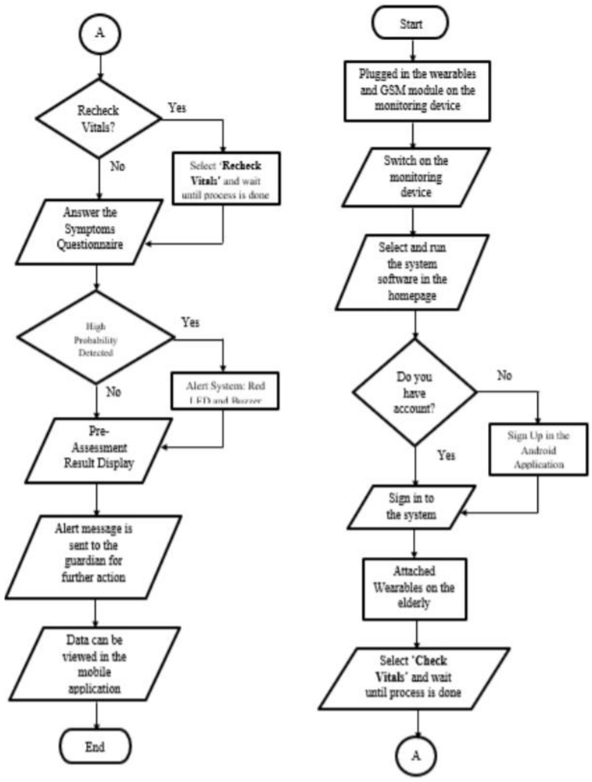

Figure 7. System Flowchart

Figure 20 shows the flowchart of the system. Wearable, GSM, and pulse oximeter devices should be installed first in the monitoring device. Once the monitoring device is setup, users should select and run the program icon for the Rescue-Wear system. Users are required to have an account in the Rescue Wear Application to have access to the service that the system will provide. This way, the elderly will have a record to the database of the system and the device will be able to save the tests done over that account. Then the wearables should be attached to the elderly that will be monitored. Select "Check Vitals" to start gathering of vital signs. After a minute, the device will show the results of the test and will also give an opportunity to the users to recheck the vitals. After gathering the vitals, symptoms and medical history related questions will be asked and will be answered through manual input of data. Random Forest Classifier will classify the data based on the input and the pre-set data that is already programmed in the system and will provide the overall health assessment. Once the system detected results beyond the normal range, the device will alert the users through the built-in alert system in the monitoring device. SMSs notification will be sent, and users will have the access to the history log through the Android application.

III. RESULT AND DISCUSSION

The objective of the proposed system is to design and developed a health monitoring system through a body sensor network using IoT Devices to provide pre-assessment results for the common elderly respiratory diseases. The system was tested for acceptance, validity, usability and accuracy.

A. Dataset

240 patient records were used for the initial prediction system of the study which comprise of affected and unaffected patients from a local health clinic. Each respiratory disease has an equivalent dataset that includes age, gender, and symptoms.

B. Prediction Model

Several classification models were developed and used to train the dataset to come up with the algorithm that will provide the highest accuracy level. These include Logistic Regression, Naïve Bayes, Random Forest Classifier and Support Vector Machine. Amongst all these algorithms, Random Forest Classifier showed the highest accuracy with of 96.97% for Bronchial Asthma and Pneumonia and 87.88% for Upper Respiratory Tract Infection (URTI).

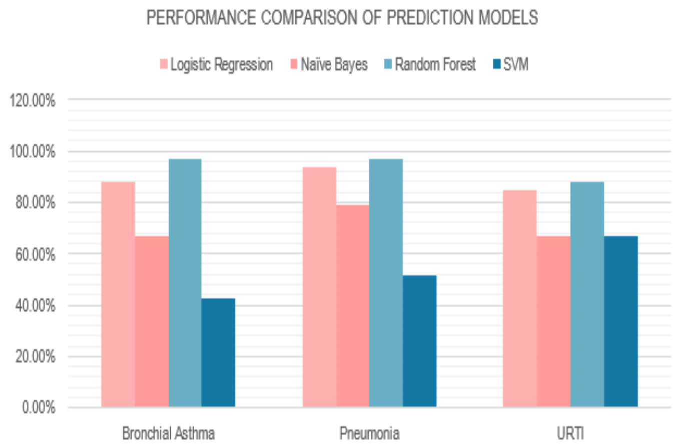

Figure 9. Accuracy Comparison Chart of Classification Algorithms

C. Sensor Accuracy Testing

Parallel testing between the device and the commercially available ones was conducted to measure the accuracy of the sensors. Testing was done several times under different individuals to get the average result. By using a mathematical equation, the proponents were able to determine the accuracy of the biomedical sensors.

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

Table 1 shows high accuracy results based on the comparison test conducted.

TABLE I. TABLE OF VITAL SIGN ACCURACY

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

D. Alert Message Notification

Using Sim800L, the proponents was able to provide text message notifications to the guardian of the elderly to keep them informed and updated about the assessments done. The system uses a prepaid SIM card which can be loaded from time to time. Under normal reception rate, the guardian will be able to receive the notification after the monitoring, however, in some areas that have poor mobile reception, there are delays detected.

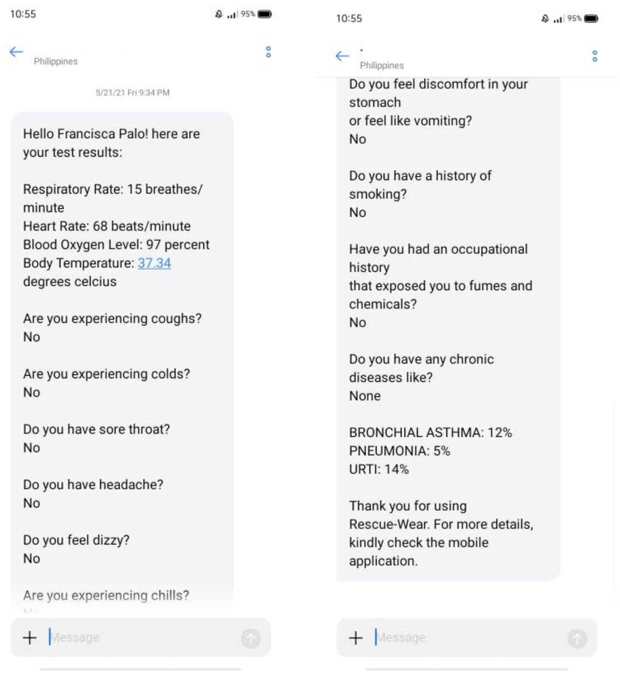

Figure 10. (a-b) Alert Message for Guardian

IV. CONCLUSION

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 home-based monitoring perfect for elderly people who have difficulty in traveling and accessing hospitals.

V. RECOMMENDATION

Based on the research findings, and for the further improvement of this study, the researchers propose the following recommendations:

- For the system design, the researchers recommend making the device more compact and portable by using different set of sensors and microcontrollers that are possibly available in the market. Also, to incorporate the system with a fix power supply by using a more lightweight power bank with a higher capacity.

- A notification for the android application must be implemented to extend the notification service of the system to keep guardians informed about the tests conducted to the elderly.
- Collection of additional datasets for the classification is highly recommended to increase the accuracy rate of the prediction.
- Furthermore, the researchers encourage to improve the system for wider range of users and to assess other illnesses like cardiovascular diseases.

VI. REFERRENCES

[1] Feng Chen, Pan Deng, Jiafu Wan, Daqiang Zhang, Athanasios V. Vasilakos, and Xiaohui Rong. Data Mining for the Internet of Things: Literature Review and Challenges, 2015.

[2] Azimi, I., Rahmani, A.M., Liljeberg, P., & Tenhunen, H. (2017). Internet of things for remote elderly monitoring: a study from user-centered perspective. Journal of Ambient Intelligence and Humanized Computing, 8, 273-289.

[3] Philippine Statistics Authority, 2015 [Online]. Available: https://psa.gov.ph/system/files/2015%20Fact%20Sheets%20on%20Senior%20Citizen_pop.pdf?width=950&height=700&iframe=true

[4] Cruz, G.T., C.J.P. Cruz and Y. Saito (eds.) (2019), Ageing and Health in the Philipines. Jakarta: Economic Research Institute for ASEAN and East Asia (ERIA).

[5] Department of Health Philippines, 2014 [Online]. Available: https://doh.gov.ph/Statistics/Leading-Causes-of-Morbidity

[6] R. Ani, S. Krishna, N. Anju, M. S. Aslam and O. S. Deepa, "Iot based patient monitoring and diagnostic prediction tool using ensemble classifier," 2017 International Conference on Advances in Computing, Communications and Informatics (ICACCI), Udupi, 2017, pp. 1588-1593, doi: 10.1109/ICACCI.2017.8126068.

[7] Peter D. Caie BSc, MRes, PhD, ... Ognjen Arandjelović M.Eng. (Oxon), Ph.D. (Cantab), in Artificial Intelligence and Deep Learning in Pathology, 2021

ABOUT THE AUTHORS

Buenavidez, Christian Lenard E. finished his studies at Paco Catholic School year 2010 – 2014. He was able to pursue a bachelor’s degree in Electronics and Communication Engineering at Technological University of the Philippines, Manila.

Familaran, Kayle Mae F. finished her studies at Tungonan National High School year 2011 – 2015. She was able to pursue a bachelor’s degree in Electronics and Communication Engineering at Technological University of the Philippines, Manila. She is also a DOST Scholar year 2015-2018.

Look, Frances Virgie P. finished her studies at Saint Claire Academy year 2011– 2015. She was able to pursue a bachelor’s degree in Electronics and Communication Engineering at Technological University of the Philippines, Manila.

Uy, Ramon Alfonso G. finished his studies at Las Piñas College year 2013 – 2015. He was able to pursue a bachelor’s degree in Electronics and Communication Engineering at Technological University of the Philippines, Manila.

Roman, Jeremias Francisco A. finished his first degree in BS Electronics Engineering Technology ate Technological University of the Philippines, Cavite. He was able to pursue a bachelor’s degree in Electronics and Communication Engineering at Technological University of the Philippines, Manila.