UNIVERSITY OF CALIFORNIA, IRVINE

MAXIM HEALTH MONITORING BAND

JUNZE HE, COMPUTER SICENCE, MT. SAN ANTONIO COLLEGE

FAUCTLY MENTOR: DR. AMIR RAHMANI,
SCHOOL OF NURSING AND DEPARTMENT OF COMPUTER SCIENCE,
UNIVERSITY OF CALIFORNIA IRVINE, USA

GRAUDATED STUDENT MENTOR: MAHYAR ABBASIAN,
DEPARTMENT OF COMPUTER SCIENCE,
UNIVERSITY OF CALIFORNIA IRVINE, USA

ABSTRACT

The purpose of the research is to integrate, validate, and deploy a health wearable device, 'MAXRFDES103', to the ZotCare platform, which is a UCI Mobile Health monitoring platform that provides tools for researchers and doctors to monitor their participants/patients online. The device can measure data like heart rate and SpO2 of a patient, but it only can collect data via a PC Maxim App and an Android MaximSensor App, which means this is inconvenient to people operating it. The first phase of the work was to investigate the device's limitations and if it could reach our expectations regarding proper data collection, data accuracy, data accessibility, and the tools that the device can provide the researchers. Then, the second phase of the work was to run a small pilot study on the device by collecting PPG data of a subject for 27 hours and using this high-quality PPG to estimate the Blood Pressure of the patient. Finally, the research focused on modification of the PC and Android mobile app of Maxim so that researchers and programmers can suppress those limitations and make it more convenient for patients to use it.

INTRODUCTION

The MAXREFDES103 uses a PPG sensor to measure data at rest, but currently, health watches are designed mostly for fitness. Health watches use ECG for data collection during activities. Both PPG and ECG use light sources at the surface of the skin on the wrist as a monitor to reflect the flow of blood (*Michael, 2021*). However, PPG has a photon detector to capture light sources and continuously record light intensity distributed by the vascular tissue (*Panicos and John 2021*). Throughout numerous experiments compared PPG to ECG, PPG is the most accurate when monitoring at rest, and ECG is more precise during activities *(Dustin et al., 2017)*. The study emphasized on measurement during resting time and only chose to collect MAXREFDES103 PPG data. Although the PPG illustrates better reading data at rest, it cannot reconstruct a complete signal sometimes (*Milad et al., 2022*). As a result, it may cause information loss if the issue happens to the device, so the investigation of the correctness of the PPG was important. Additionally, the lab investigated the limitations of other wearables that users cannot access raw data; they are not accurate and are free to be modified. These are the reasons that the study tried to see if MAXIMRFDES103 could be a good replacement. The project proposed questions that were going to be answered during the research.

1. What capabilities does the device have?
2. Can the device predict accurate blood pressure by using the PPG sensor?
3. Can researchers modify the firmware of the device?
4. Can researchers modify the App of the device?
5. Can researchers agave the raw data and connect the device to the ZotCare platform?

According to the questions, the researchers address them by using these three strategies:

1. Testing if the phone app can run in different conditions

2. Substantiating if the PPG of the device is accurate
3. Finding the source code of the phone app

METHODS

The first task was to realize the capabilities of the device and test the App to check if three conditions ceased a measurement. The first testing condition was to run the phone app in the background. The researchers ran the App on an Android phone and started a measurement. After monitoring started for 5 seconds, the researchers ran the App in the background for 10 seconds. Running the App in the background and locking the phone screen were the second testing conditions. The process was like the first testing condition above, but the researchers locked the screen and ran the App in the background for 10 seconds. The last testing condition was to quit the App. After monitoring for 15 seconds, the researchers closed the App.

In terms of modification, the study had to seek an open source code of the phone app to change in the future. The researchers needed to consult the information about the firmware and the App from a technician in Maxim Integrated Company. Moreover, the researchers found a complete application of the device on GitHub, and the technician provided the researchers with the code of the App as well. Then, the researchers judged which was apt to be modified based on the programming language selection, compatibility with which system, and time to code.

In this testing, the researchers needed to use the MAXREFDES103 to collect PPG and a blood pressure monitor to measure the actual blood pressure that including heart rate, systolic value (unit: mmHg), and diastolic value (unit: mmHg). The researchers used the MAXREFDES103 with the PPG to predict blood pressure (predicted blood pressure: predicted BP) for an hour while gathering the actual blood pressure (Actual BP) by the monitor every 10

mins. After that, the researchers programmed in python to convert the PPG to blood pressure as a graph. Then, the researchers compared the graph of the PPG in the device to a high-quality PPG sample. Moreover, the researchers ran programming algorithms to calculate the mean differences between the blood pressure from the monitor and the blood pressure from the monitor.

REUSLTS

The capabilities of the device are few, but it provides the ability to collect raw data. The storage of the device depends on the storage of the PC or the Android phone that users connect with. If a PC can store 50 GB, the device can measure 50 GB data. The device lasts for 9 hours and takes 250 minutes to charge fully. Additionally, it can collect raw data, which is a set of data from a device has not been processed (Panicos). Whereas the researchers can analyze how the device process data and plot raw data to a graph to see if they are precious.

The last condition only discontinued the measurement, closing the App, when reopening the App. This meant the device could not monitor without opening the App. It is not convenient for patients to use it. As a result, the researchers will need to change the device and the App to allow the Wi-Fi setup. Even though the last condition broke off the monitoring, all the testing conditions resulted in the conducting of an available measurement. The App saved the data files in a drive after measurement in three different conditions. It did not have any errors with how long it took to measure. Even if a patient uses it to monitor for a second, the measurement is still available. Overall, a patient has to open the App to measure data like heart rate.

The researchers compared the code on GitHub to the code from the company; the researchers preferred the code on GitHub. On the one hand, the code on GitHub was a complete Android application, including Bluetooth, reading data, and saving data. The researchers will not code

these capabilities without bases. The application was programmed in Kotlin, which was adapted to mobile Android App development. On another hand, the code from the Maxim Integrated company will be difficult to be modified because the code was incomplete and was not prepared to run on any device. Even though it was programmed in C++ and performed the code efficiently, it lacked the code of Bluetooth, reading data, and saving data. Worse still, it did not demonstrate which system it was compatible with, so I would have built the compatibility in the future. If the researchers used the code from the company, the tasks would overwhelmingly delay the progress of the project.

The PPG of the device was accurate compared to the high quality of the PPG graph (table1) from the book, 'Photofluorography' by Panicos. Excellent quality of PPG has to indicate the systolic peak and the diastolic peak. Systolic peak and diastolic are two numbers of the pressure in a patient's arteries when a patient's heart beats (*CDC*). In table 1 shown below, the systolic peak is the largest projection, and the diastolic peak is the smallest projection on the waves. The diastolic peak always follows the systolic peak to shape into two different sizes of the peak. This is a sign of the high quality of PPG. In table 2 shown below, the PPG of the device exactly matches the excellent quality. Furthermore, the researchers tested the PPG by using computational algorithms on a computer. The PPG of the device was arcuate since the researchers got the lower P, MAE, and RMSE values. The first row is for the systolic, and the second row is for the diastolic. The researchers calculated the mean differences in different formulas. In table 3, the first formula is MAE, which is the mean absolute error to calculate the main differences between the data points from the predicted BP and the actual BP. The second formula is RMSE, which finds the average differences in distance errors between the values from predicted BP and the actual BP. The last column is the P, which is the value of correlation

between the predicted BP and the actual BP. As a result, the wearable device can help patients collect precious data and is a good replacement for collecting raw data.

Table 1: The High Quality PPG Sample

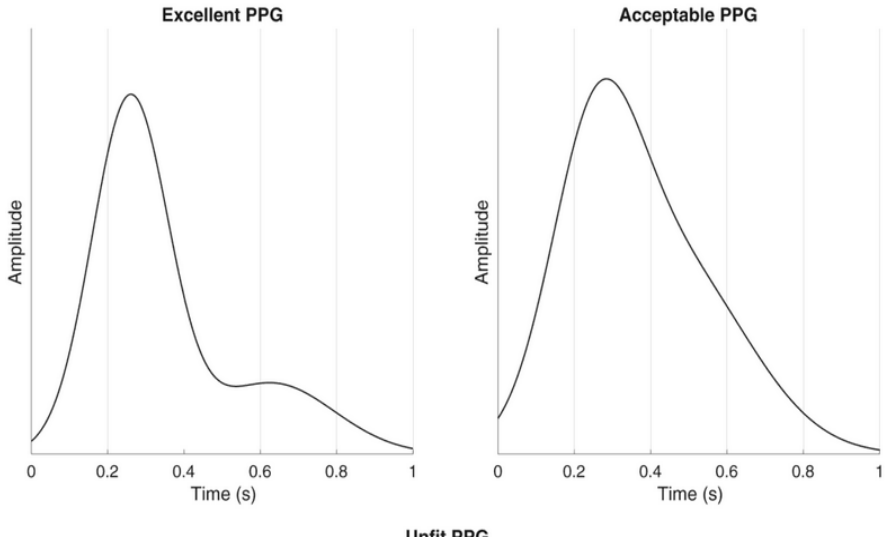

Table 2: The PPG Sample Of The Device

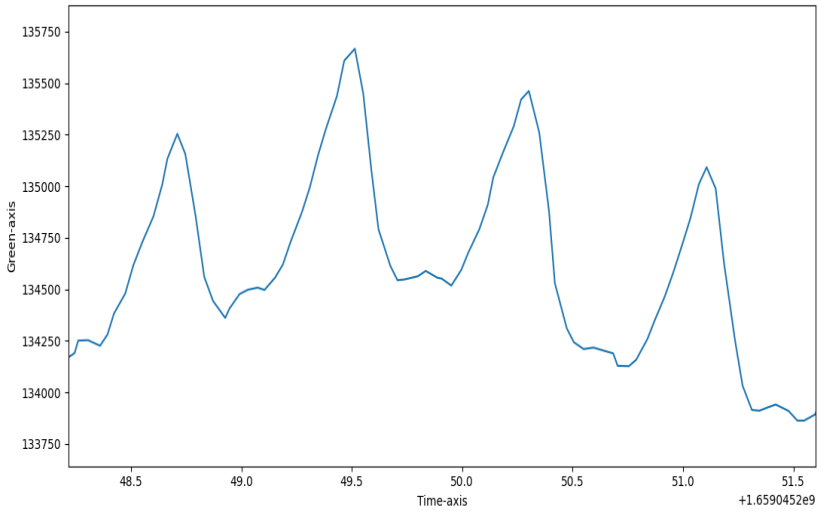

Table3: The Values of MAE, RMSE, And P Generated By Python

	MAE	RMSE	P
SBP (systolic BP)	2.96	5.34	<0.001
DBP (diastolic BP)	3.49	5.01	<0.001

RMSE Formula: $\sqrt{\text{E (pi} - \text{ti)\^2)/N}}$
pi: total actual data points ti: predicted data points N: total data points
E: sigma which is summing all values of estimated BP data and actual BP data

MAE Formula: (E |pi-ti|)/N
pi: total actual BP data values ti: total predicted BP data values N: total data values
E： the definition is the same as above

P: Pearson Correlation Formula: $\mathrm{P} = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2}}$

x_i: Predicted BP, y_i: actucal BP, $\bar{x}$: mean predicted BP, $\bar{y}$: mean actucal BP

Discussion

There are some disadvantages and there is an advantage between the MaximSensor App and the MAXIMREFDES103. The most important issue is that it eased the measurement after closing the App, so the researchers have to modify the App in the future. After communication with the technician, the technician explained that the firmware was encrypted, and the researchers could not change it. The code from GitHub will help the researchers save time to change the App compared to the code from the company. The main reason was that the code from the company lacks the code for Bluetooth, reading data, and saving data. These are the drawbacks of the device, but the advantage of the device is that the PPG is accurate. The PPG sensor of the device can consistently generate high-quality results for the PPG. As a result, the PPG can help the researchers do the more precious analysis of patients' information.

ACKNOWLDGEMENT

I honestly appreciate my faculty mentor, Dr. Amir, and my graduate student mentor, Mahyar, for the guidance of the project. They were patient to answer my technical questions about the PPG and the coding during the research. I would like to thank Dr. Iraj and Dr. Alvin Kung as the program investigators. They helped us contact labs at UCI and UCR to ensure every student had a spot in a lab to conduct their own research. I would also like to thank Dr. Said as a research consultant who attended our weekly Friday meetings sometimes and provided us with suggestions for our presentation. Eventually, I am grateful to the National Science Foundation, NSF (Award#2024276). The NSF granted funding for the research program and provided me with an excellent undergraduate research experience.

WORKS CITED

CDC, "High Blood Pressure Symptoms and Causes", *CDC*, https://www.cdc.gov/bloodpressure/about.htm

Dustin T. Weiler, Stefanie O. Villajuan, Laura Edkins, Sean Cleary, Jason J. Saleem, "Wearable Heart Rate Monitor Technology Accuracy in Research: A Comparative Study Between PPG and ECG Technology ", *SSGAE JOUNARAL*, 20 Oct, 2017 https://journals.sagepub.com/doi/abs/10.1177/1541931213601804?journalCode=proe

Milad Asgari Mehrabadi, Seyed Amir Hossein Aqajari, Amir Hosein Afandizadeh Zargari, Nikil Dutt, Amir M. Rahmani, "Novel Blood Pressure Waveform Reconstruction from Photoplethysmography using Cycle Generative Adversarial Networks", *Cornell University*, 24 Jan, 2022, https://arxiv.org/abs/2201.09976

Maxim Integrated, "MAXREFDES103#: Wrist-Based SpO_2, HR, and HRV Health Sensor Platform", *Maxim Integrated*, https://www.maximintegrated.com/en/design/reference-design-center/system-board/7141.html

Michael Sawh, "ECG smartwatches explained: How they work and the best on the market", *WEARABLE*, 9 May, 2022, https://www.wareable.com/health-and-wellbeing/ecg-heart-rate-monitor-watch-guide-6508

Panicos A. Kyriacou, John Allen, “PHOTOPLETHYSMOGRAPHY, TECHNOLOGY, SIGNAL ANLYSIS AND APPLIACTION”, *University of London, Coventry University*, 21 May, 2021

THE TIME OF INIDA.COM, “Fitness bands vs smart watches: Which is the right fit for you.”, *The Time OF INIDA, 29* Sep. 2021, https://timesofindia.indiatimes.com/gadgets-news/fitness-bands-vs-smart-watches-which-is-the-right-fit-for-you/articleshow/86615334.cms