TEST Engineering & Management

May – June 2020
ISSN: 0193-4120 Page No. 2349 - 2355

Edge Intelligence and Cloud Computing Health Monitoring System

[1]ONagamani, [2]BTPMadhav, [3]NGovind Rao, [3]Govardhan Mattela, [4]Raja Sekhar P V
[1]Research Scholar, Dept. of ECE, Koneru Lakshmaiah Education Foundation,Andhra Pradesh, India
[2]Professor, Dept. of ECE, Koneru Lakshmaiah Education Foundation(KLEF), Andhra Pradesh, India
[3]Redpinesignals India PVT Ltd, Hyderabad, Telangana, India.
[4]Dept. of Physics, SR Engineering College, Warangal, Telangana, India

Article Info
Volume 83
Page Number: 2349 - 2355
Publication Issue:
May - June 2020

Abstract:

Now-a day's most individuals are suffering from heart failure caused due to coronary artery disease. Coronary artery disease occurred because of the buildup of fatty deposits within the arteries. It will be expected to increase because of the present social lifestyle. Individuals who experience the ill effects of coronary artery disease will have many hazard factors like hypertension and weight have been expanding. Heart failure and blood pressure prediction in the population will help us to reduce coronary artery disease (cardiovascular mortality).

In this paper, the main motive is to update the "heart rate and blood pressure" results to the cloud and mobile phonewith the assistance of BLE and WI-FI for at regular intervals (5 minutes).

For data acquisition, we used the photoplethysmography sensor (MAX30105). By processing the PPG signals, the heart rate and blood pressure parameters are obtained. These parameters are given to a machine learning algorithm for getting accurate blood pressure and heart rate values.

The MAX30105 sensor module contains the twin - LED with 660nm (Red LED) and 905 nm (Infrared LED) wavelengths, with a sampling rate of 200 Hz. Right now, we are contemplating the PPG signal filtering, highlight extraction, and demonstrating. Espial of heart rate, systolic blood pressure and diastolic blood pressure with the root mean squared error (RMSE) of 7.90 beats every moment, 10.95 mmHg and 8.90 mmHg among Sphygmomanometer and PPG from five-crease cross-approval technique.

Article History
ArticleReceived*: 11August 2019*
Revised*: 18November 2019*
Accepted*: 23January 2020*
Publication*:10May2020*

Keywords:*coronary artery diseases, Wise MCU(RS14100), photoplethysmography, Blood pressure and Heart rate(BP-HR)*

I. INTRODUCTION

Nowadays biomedical technologies are changed drastically to simplify the analysis of signals. And a lot of methods have arrived for improvement of health checking, which can communicate wirelessly[1]. And the power utilization of the system is exceptionally low. Improvement of such thought of devices is basic as they help in the acknowledgment of variations from the norm. Because of continuous checking, this system is utilized for crisis reasons in the medical field.

Economical systems are being implemented (advanced) for continuous observation of the patient's health condition. Health monitoring covers various physiological signals and quantification of these signals will be sensed by photoplethysmography and temperature embedded sensors.

Generally, the blood pressure can be evaluated with the cuff-based devices. Some patients will feel uncomfortable with the cuff-based devices. So, the proposed system using the non-obtrusive method. The system comprises of IR sensors which are

May – June 2020
ISSN: 0193-4120 Page No. 2349 - 2355

utilized to consistently procure the PPG signal. Which leads to monitor the BP-HR consistently [18]. BP is an estimation of the power applied to the veins during blood flowing to the heart which is diminished as it moves from the heart through corridors and vessels, and toward the heart through veins [2].

For every heartbeat, blood pressure (pulse) measurement changes among systolic and diastolic blood pressures[18]. The systolic blood pressure (SBP) is characterized as the most elevated weight which happens when the blood experiences blood vessel dissemination to the heart at the hour of constriction. The diastolic blood pressure (DBP) is characterized as the blood that experiences the blood vessel dissemination to the heart at the time relaxation(unwinding) [6,7].

Generally, the blood pressure is measured with the help of a sphygmomanometer. The sphygmomanometer comprises a combination of the cuff and glowing up the bulb with a manometer and a release valve. A manometer is a gadget that is utilized for the reflection of the circulating pressure with the help of mercury column height.

Over 100 years of sphygmomanometer has been the "most excellent level" in non-prominent estimation. These days the circulatory strain esteems are estimated with the mercury in milli-meter(mmHg).Nanotechnology guarantees a superior development in medical technologies which hopefully continuous human strength.

Photoplethysmography (PPG) is used to study cardiovascular circulatory information in measuring heart rate, blood pressure[2].

Heart failure is a significant reason for most deaths. Besides, the coronary artery decease has relied upon the increment in the future because of the ecological contamination, lifestyle, stress and other factors[4]. These factors lead to a cause of coronary artery decease. The coronary artery diseases can be predicted with the help of BP-HR. Photoplethysmography (PPG) is a technique for the estimation of blood fluctuations with the assistance of infrared light. Heart rate, blood pressure, and respiratory system functionality can also be analyzed with the help of PPG signal processing[6]. PPG signal processing has many advantages like non-obtrusive, low cost and most efficient diagnostic tool in the health monitoring system.

II. Review of literature

In their studies, Mohamed Elgendi implemented a non-obtrusive detection method for the measurement of BP and coronary artery deceases with the help of ppg signals sensed from the fingertips. He analyzed the SBP, DBP & HR from 40 features that are taken from the PPG signal. He applied the primary & secondary derivatives for noise filtering[5].

Yongbo et al, in their study, implemented a non-obtrusive detection of BP &coronary artery decreaseswith the help of the PPG signals that are sensed from the fingertips. They also performed research on the people in China who have age ranges from 20-89 years. He acquired the data for blood pressure from the 219 subjects contains 657 data segments from these people. Their discussions will result to indicate hypertension and diabetes[6].

Gonzalo Tapia in their study, Investigate the finger arterial pressure waveform using the derivative approaches. His study will give information about the SBP & PTT when an implanted BP sensor is employed[7].

In another study, Mohamed Elgendi investigated the various filtering techniques applied for the PPG signal. He classified the filters based on the signal quality index(SQI) which might be developed from the zero crossings, skewness, entropy,relative power,kurtosis, non-stationary, perfusion, & the matching systolic wave detectors[8].

Young-Hua Kao in their study developed the non-invasive photoplethysmography-blood pressure device with a self-adaptive system. His study mainly deals with the hardware equipment of the self-adaptive system for increasing the SNR ratio[9].

III. Proposed Methodology

The Edge Intelligence smart health-care system comprises of 4 blocks – data acquisition, data pre-

May – June 2020
ISSN: 0193-4120 Page No. 2349 - 2355

processing, feature engineering and AI algorithm. The sustained and accurate SBP, DBP and HR will be obtained after the AI- algorithm.

A) Data acquisition

The data is acquired from the MAX30105 module contains twin-LED. These are infrared led and red led with 950nm and 660nm wavelengths correspondingly operates with the sampling rate of 200 Hz. And also having the inbuilt 2-bit ADC. The MAX30105 sensor connected to the wiseMCU to fetch the data. Our system we are using the infrared led to detect the blood fluctuation in the arteries.

The MAX30105 sensor will work on the principle of reflectance and transmission. The MAX30105 sensor is embedded on the wiseMCU and data is acquired from the left index finger[6].

The PPG data is analyzed by 60 people. The data is acquired from each person for 5 minutes. We have recorded the (5 PPG measurements X 60 people at 5minutes of each). The blood pressure is monitored with more open BP one(more open, china) at the upper arm.

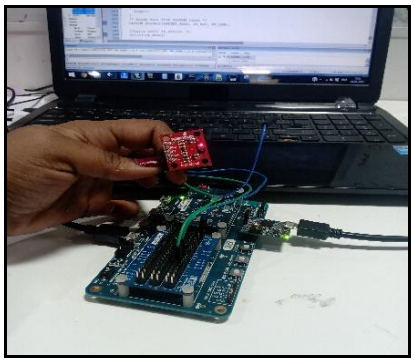


Fig:1.PPG sensor initialization and the data acquisition from the left index finger.

B) Data Pre-processing

The PPG signal is acquired in the indoor environment only. But due to it's low frequency, a small amount of noise signal also will interrupt the ppg signal[8].

To get the accurate blood pressure and heart rate we need to reduce the noise[18]. So, we have implemented a butter worth filter having a cut off frequency of 1Hz to 12Hz. After that, the signal is given Infine Impulse Response filter(IIR) of having a cut off frequency of 50Hz. The obtained filtered signal skewness factor is greater than 0.6. If the obtained signal skewness is less than 0.6 then those signals are discarded. We also analyzed the probability distribution of skewness for symmetrical wave-forms[11].

C) Feature Extraction

The obtained ppg signal from the filter is periodic in nature. We are mapping the filtered signal with the functionality of hearrate.The filtered signal is divided into 2 parts. i.e, catacrotic phase and anacrotic phase.The catacrotic phase is obtained in DBP and is defined as the falling edge of the pulse. And the anacrotic phase is obtained in SBP and is defined as the rising edge of the pulse. The cardiac cycle is represented by each phase. The cardiac cycle is the combination of the diastolic phase and the systolic phase corresponding to the SBP and DBP. The catacrotic phase also consists of the dicrotic notch (or) aortic notch. Dicrotic notch is are occurred due to the reflections from the periphery of the healthy person.

According to the heart rate functionality, we have observed so many phases in one minute of the obtained signal(ppg)[8]. For an accurate evaluation of the BP-HR, we have extracted many diagnostic features like pulse width, systolic pulse area, systolic amplitude, diastolic amplitude, dicrotic notch, pulse interval, augmentation index and peak to peak interval [12]. These features are extracted for each phase of the ppg signal. For the accurate measurement of BP-HR, we are using machine learning algorithms. Feature extraction is vital in machine learning algorithms. From the machine learning algorithms, we have obtained accurate systolic SBP, heart rate, and diastolic DBP as shown in Table1.

TABLE 1
Derived features of SBP, heart rate, and DBP

Obtained response	Parameters used for response
SBP	Systolic amplitude, diastolic amplitude, dicrotic notch, pulse

May – June 2020
ISSN: 0193-4120 Page No. 2349 - 2355

HR	area, pulse width, pulse interval, augmentation index and peak to peak interval
DBP	

D) Regression Models

The regression models of SBP, HR, and DBP are administrated with non-linear and ensemble machine learning algorithms like multiple linear regression(MLR), the k-nearest neighbor algorithm(K-NN) and decision trees[13]. All these models were trained, tested to evaluate the performance(R^2) and root mean square error (RMSE). The PPG data preprocessing, feature extraction and regression models were administrated with the PYTHON software (Version 3.7.2, 2018).

E) WiseMCU(RS14100)

The PPG sensor is directly embedded on the wiseMCU (RS14100) body. The module will fetch the information from the PPG sensor. Redpine Signals' RS14100 SoCs are Wireless Secure MCUs that have a multi-protocol wireless sub-system. It is an ultra-low-power microcontroller system. It has a single radio on-chip can be configured for wi-fi as well as Bluetooth applications. It consumes less power because it can be used in standby associated mode.

An ARM Cortex-M4F running up to 180MHz and Redpine'sThreadArch 4-Threaded processor running up to 160MHz. The Cortex-M4F is dedicated to peripheral and application-related processing whereas all the networking and wireless stacks run on independent threads of the ThreadArch.

F) Hardware Implementation

The PPG sensor is directly embedded on the wiseMCU(RS14100) body. The module will fetch the information from the PPG sensor. Initially, the services corresponding to the BP-HR are added to the BLE advertiser. The mobile phone will act as the BLE central device and is connected to the wiseMCU via the bi-medical app. The notifications are enabled in the connection. For every 5 minutes, the BP-HR information is updated in the mobile phone via a BLE connection with wiseMCU. The same information is updated to the cloud via the MQTT protocol. The data can be updated to the cloud in many ways. With the help of module and mobile. i.e, The RS14100 is connected to the nearby internet-enabled access point. In this manner, the information is updated via RS14100.

IV. Results

The estimation of SBP, HR, and DBP were reported[14]. In this paper, we have analyzed the extensive signal processing, feature engineering and modeling of SBP, HR, and DBP with the help of ppg signal processing. The results were presented in Tables 2-4.

TABLE-2.
Regression modeling for HR using multiple linear regression, K-nearest neighbors and decision trees.

Regression models	RMSE		
	Trained value	Fivefoldvalidationtheory(cross)	Obtained values
Multiple linear regression	7.68	7.90	8.10
KNN	10.25	9.50	10.36
Decision trees	10.19	11.50	9.36

TABLE-3.
Regression modeling for SBP using multiple linear regression, k-nearest neighbors and decision trees.

Regression models	RMSE		
	Trained value	fivefold validation heory(cross)	Obtained value
Multiple linear regression	10.11	10.95	9.15
KNN	11.50	12.15	11.36
Decision trees	11.21	11.34	12.20

May – June 2020
ISSN: 0193-4120 Page No. 2349 - 2355

TABLE-4.
Regression modeling for DBP using multiple linear regression, k-nearest neighbors and decision trees.

Regression models	RMSE		
	Trained value	fivefold alidation theory(cross)	Obtained value
Multiple linear regression	9.30	8.90	9.34
KNN	11.66	13.21	12.42
Decision trees	11.30	12.22	11.20

From the study of multiple linear regression, k-nearest neighbors and decision trees for systolic blood pressure, heart rate, and diastolic blood pressure. The multiple linear regression algorithm is achieved superior performance results than the other two regression algorithms between Sphygmomanometer and PPG from the five-fold cross-validation method.

The data from the machine learning algorithm i.e, SBP, DBP, and HR are updated to the mobile via BLE connection and to the cloud via wi-fi(access-point) connection.

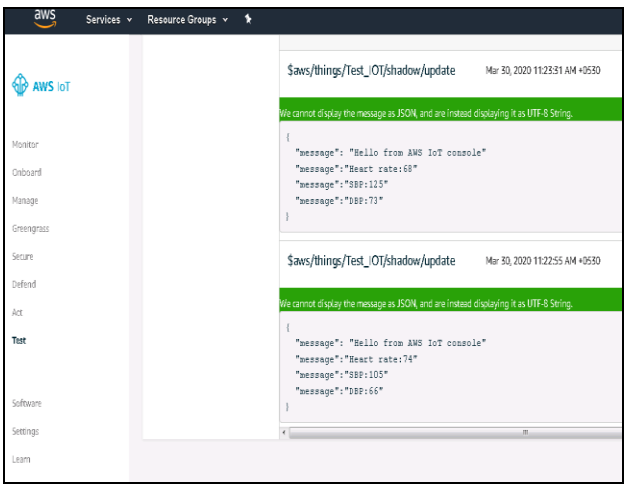
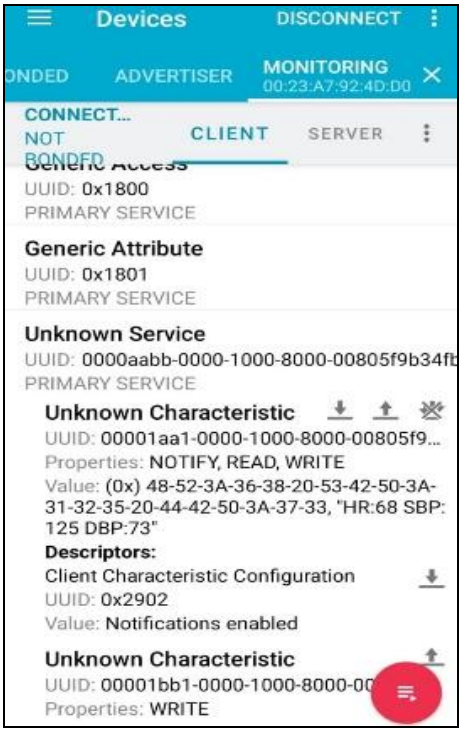
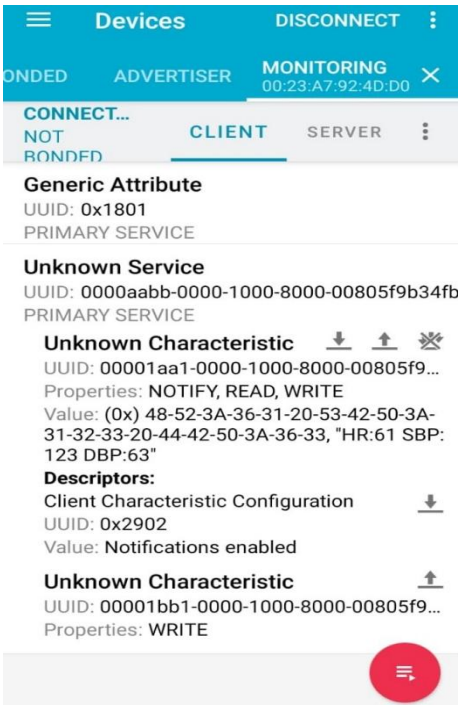


Fig.2.sensor data updating in Cloud



(a)

Fig.3(a). sensor data updating in BLE



(b)

Fig.3(b). sensor data updating in BLE

V. Conclusion

The main theme of this concept is to implement edge intelligence and cloud computing health monitoring device. This system is used for the detection of BP-

May – June 2020
ISSN: 0193-4120 Page No. 2349 - 2355

HR using PPG signals. The proposed methodology describes the PPG signal data acquisition, signal processing, feature extraction, feature selection and machine learning algorithms for detection of heart rate and blood pressure. The obtained BP-HR from the algorithm will transmit to mobile via BLE connection and to cloud via wi-fi connection (access point).

References

1. Allen J. Photoplethysmography and its application in clinical physiological measurement. Physiol Meas. 2007, 28,R1-R39.
2. Awad A, Haddadin A, Tantawy H, Badr T, Stout R, Silverman D, et al. The relationship between the photoplethysmographic waveform and systemic vascular resistance. Journal of Clinical Monitoring and Computing. 2007;21(6):365–72.
3. Yongbo Liang, Zhencheng Chen, Guiyong Liu & Mohamed Elgendi. A new, short-recorded photoplethysmogram dataset for blood pressure monitoring in China. Scientific Data, volume 5, Article number: 180020 (2018).
4. Mohamed Elgendi, Richard Fletcher, Yongbo Liang, Newton Howard, Nigel H. Lovell, Derek Abbott, Kenneth Lim, Rabab Ward. The use of photoplethysmography for assessing hypertension. npj Digital Medicine, 2, 602019.
5. Yongbo Liang, Zhencheng Chen, Guiyong Liu & Mohamed Elgendi. A new, short-recorded photoplethysmogram dataset for blood pressure monitoring in China. Scientific Data, volume 5, Article number: 180020 (2018).
6. Tapia, Gonzalo & Salinas, Matias & Plaza, Jaime &Mellado, Diego & Salas, Rodrigo & Saavedra, Carolina &Veloz, Alejandro & Arriola, Alexis &Idiaquez, Juan &Glaria, Antonio. (2017). Photoplethysmogram Fits Finger Blood Pressure Waveform for non-Invasive and minimally-Intrusive Technologies - Evaluation of Derivative Approaches. 155-162.
7. Elgendi M. Optimal Signal Quality Index for Photoplethysmogram Signals. Bioengineering (Basel). 2016;3(4):21. Published 2016 Sep 22. doi:10.3390/bioengineering3040021.
8. Kao, Yung-Hua et al. “A PPG sensor for continuous cuffless blood pressure monitoring with self-adaptive signal processing.” 2017 International Conference on Applied System Innovation (ICASI) (2017): 357-360.
9. Liang, Yongbo&Elgendi, Mohamed & Chen, Zhencheng& Ward, Rabab. (2018). An optimal filter for short photoplethysmogram signals. Scientific Data. 5. 180076. 10.1038/sdata.2018.76.
10. Chen S, Ji Z, Wu H, Xu Y. A Non-Invasive Continuous Blood Pressure Estimation Approach Based on Machine Learning. Sensors (Basel). 2019;19(11):2585. Published 2019 Jun 6.
11. Elgendi M. On the analysis of fingertip photoplethysmogram signals. CurrCardiol Rev. 2012;8(1):14–25.
12. S. S. Bashar, M. S. Miah, A. H. M. Z. Karim, M. A. Al Mahmud and Z. Hasan, "A Machine Learning Approach for Heart Rate Estimation from PPG Signal using Random Forest Regression Algorithm," 2019 International Conference on Electrical, Computer and Communication Engineering (ECCE), Cox'sBazar, Bangladesh, 2019, pp. 1-5.
13. S. S. Bashar, M. S. Miah, A. H. M. Z. Karim, M. A. Al Mahmud and Z. Hasan, "A Machine Learning Approach for Heart Rate Estimation from PPG Signal using Random Forest Regression Algorithm," 2019 International Conference on Electrical, Computer and Communication Engineering (ECCE), Cox'sBazar, Bangladesh, 2019, pp. 1-5.
14. A. E. Awodeyi, S. R. Alty and M. Ghavami, "On the Filtering of Photoplethysmography Signals," 2014 IEEE International Conference on Bioinformatics and

May – June 2020
ISSN: 0193-4120 Page No. 2349 - 2355

Bioengineering, Boca Raton, FL, 2014, pp. 175- 178.

15. Nidigattu, Govinda Rao, Govardhan Mattela, sayanJ.,Non-invasive modeling of heart rate and blood pressure from a photoplethysmography by using machine learning techniques
16. Xiaomanxing., Mingshan sun., Optical blood pressure estimation with photoplethysmography and FFT-based neural networks, Vol. 7, No. 8 | 1 Aug 2016.
17. Andriy Temko., Accurate Heart Rate Monitoring during physical exercises using PPG DOI: 10.1109/TBME.2017.2676243
18. Rubins, Uldis, Grabovskis, Andris, Grube, Jurgis., Photoplethysmography analysis of artery properties in patients with cardiovascular diseases
19. SeungMin Lee., Effective PPG Sensor Placement for Reflected Red and Green light, and Infrared Wristband-type Photoplethysmography.
20. Tapia, Gonzalo, Salinas, Matias, Plaza, Jaime.,Photoplethysmogram Fits Finger Blood Pressure Waveform for non-Invasive and minimally-Intrusive Technologies-Evaluation of Derivative Approaches