Towards IoT and ML Driven Cardiac Status Prediction System

Md. Ittahad Uz Zaman
Dept. of CSE
United International University
Dhaka-1212, Bangladesh
mzaman152134@bscse.uiu.ac.bd

Shaira Tabassum
Dept. of CSE
United International University
Dhaka-1212, Bangladesh
stabassum152129@bscse.uiu.ac.bd

Md. Sabbir Ullah
Dept. of CSE
United International University
Dhaka-1212, Bangladesh
mullah152144@bscse.uiu.ac.bd

Ashikur Rahaman
Dept. of CSE
United International University
Dhaka-1212, Bangladesh
arahaman152135@bscse.uiu.ac.bd

Samsun Nahar
Dept. of CSE
United International University
Dhaka-1212, Bangladesh
snahar152117@bscse.uiu.ac.bd

A.K.M. Muzahidul Islam
Dept. of CSE
United International University
Dhaka-1212, Bangladesh
muzahid@cse.uiu.ac.bd

***Abstract*—The amount of death rate in Bangladesh because of different types of non-communicable cardiac diseases are rapidly increasing every year. These non-communicable diseases are long-term and slowly progressive and become so severe that the condition of patient is too critical to handle. As a result, most of the people got sudden heart attack or learn about their disease when it is too late. Thus, in this paper, we propose an IoT and Machine Learning derived cardiac status prediction method that can collect necessary data from human body using IoT devices (sensors) and transfer those data to cloud where the data are stored with user authentication. The data which are received from human body are then to be normalized before machine learning algorithms are applied into them to calculate and predict overall condition of a patients heart. To-date we could collect heart rate, ECG signal and cholesterol through IoT devices from human body. The results we have received of heart rate and cholesterol are quite satisfactory. There are still some issues with the interpretation of the ECG signal which we are working on to improve.**

***Index Terms*—IoT, Machine Learning (ML), Cardiovascular Disease (CVD), ECG, Cholesterol, Heart Rate.**

I. Introduction

Cardiovascular Disease (CVD) and Coronary Artery Disease are two increasing cause of mortality nowadays in Bangladesh. Over the last few decades, the main reason of death has dramatically shifted from communicable disease e.g.Cholera, Smallpox to non-communicable e.g. Cardiovascular disease, Cancer, Blood pressure, Diabetes disease. Previously from a statistics of 1986 the morbidity and mortality for the communicable disease were 52% and for the non-communicable disease, it was 8% [1]. But according to some studies done in 2014, it has been found that the main cause of death has dramatically shifted to non-communicable disease from communicable disease, which is quite severe in the sense because non-communicable disease like Cardiovascular disease is the most fatal reason of death bearing the statistics of 17% alone [1]. The effect is higher in urban areas although the available treatment for the cardiac disease is quite costly. So looking through different aspects of CVDs in our country it is safe to say that, this side needs some attention and some measures have to be taken to monitor the cardiac condition as well as to get useful suggestions or alerts for upcoming anomalies of a person's cardiac condition.

Thus, in this paper, we describe a prototype which will automate the whole task of data collection and transferring the data with the help of IoT devices to an application running a Machine Learning algorithm on the cloud, which will then calculate the result based on the inputs collected from different IoT devices and sensors connected to the patient or user-end in real time. The ML algorithm is provided with 12 parameters to get a prediction about the possible cardiac anomalies.

Cardiac diseases are highly prevalent in Bangladesh. The death rate is increasing rapidly due to the rising amount of heart attacks, Coronary Artery Disease, Cardiovascular Disease (CVD). According to the Global Health Observatory data of the World Health Organization in 2017 Bangladesh is ranked 104 in the world with 14.31% of total deaths.

According to the recent Non-communicable Diseases Country Profiles of Bangladesh provided by WHO, amount of people who are taking drug therapy to prevent heart attacks and strokes are negligible. People are barely conscious of non-communicable diseases but these long-term and slowly progressive diseases are so severe in future that condition of the patient becomes too critical to handle. According to Bangladesh criteria, people hardly follow a regular checkup or feel the necessity to counsel a doctor even once a month. As a result, most of the people got a sudden heart attack or get to know about their disease when it is too late. So all of these situations motivated us to come up with IoT devices based ML driven heart condition monitoring system. A device that will take all the necessary sensitive and private data from human body such as Cholesterol, Heart rate, ECG, Blood sugar and Blood pressure and so forth with the help of IoT devices and our Machine Learning algorithm will calculate the result and

provide the overall heart condition of the patient.

Blood pressure monitor, glucose meter devices are popular and useful among people as these devices measure blood pressure, blood sugar level which let people know their current health status within a minute. This service is not available yet for the non-communicable disease patients. Hence, a device that can let people learn about their current heart condition will be helpful to take the necessary preventive steps at the right time.

The rest of the article is organized as follows. Section II provides a review on existed works related to IoT based health monitoring systems. Section III presents our proposed methodology on cardiac diseases detection and Section IV demonstrates our experimental analysis and results. Finally, Section V is the conclusion including our future progress and improvement.

II. Related Work

In this section, we have reviewed the existing works related to cardiac issues that already have been done or people still are working on.

A. Blood Pressure and Heart Rate

There is a paper by Snehal Sanjay Kale et al. in [2] where they introduced BSN technology, which is consisted of low-power and lightweight wireless sensor nodes, such as temperature sensor, heart rate sensor to collect blood pressure and heart rate of a patient. These devices are placed on the human body to monitor the health condition of a patient at home and all of these collected health-related parameters will be sent to their physician's server using a long-range wireless technology.

We-Care [3] is an IoT based health care system which introduced We-watch wristband using a SensorTag from Texas Instruments. This wristband is for elderly people which collects blood pressure, humidity from the human body. It can also detect a sudden fall of the patient. The Fall Detection system is implemented by reading the accelerometer data which is used to detect sudden movements, like falls, and also to track any movement activity performed by the elderly person.

A paper by P.Gupta [4] presented an IoT based system which provides emergency medical service by collecting data information through health status monitors including heart rate, blood pressure, and ECG. These pieces of information are sent to the patient's doctor as an emergency alert with full medication information.

In paper [5], Johan Bhurney et al. used the photoplethysmography method via the PPG sensor to detect the variations in blood volume and blood flow in the body.

B. Electrocardiography

In paper [6] the authors have proposed a health monitoring and measurement system by inexpensive wearable sensors. The sensor will collect some physiological parameters and will transmit the data to a gateway server via Bluetooth. The physiological biomarkers that are taken into consideration are ECG, Respiratory rate, Skin temperature, and EMG muscle movement.

Paper [7] mainly focuses on electrocardiogram of a patient through IoT enabled sensors. Despite conventional clinical ECG equipment has 12-lead system, this proposed system implements 3-lead placement in a triangular fashion around the heart. The data is processed through an MCU and sent to the cloud with wireless access points.

In work [8] the researchers mainly worked on developing a software infrastructure that supports ECG signal analysis for feature extraction and classification for diagnosing the heart condition. The features space extracted for the ECG signal led to an accuracy of 98.7%. They also made it clear that ECG analysis and classification can be done in real time.

Paper [9] describes the way of measuring physiological ECG data using single board computer with the help of e-health sensor platform. The ECG data is processed to get the Heart Rate(HR) and Heart Rate Variability (HRV) which later on will be used to diagnose major diseases.

C. Glucose and Cholesterol

In the work by Meghana chandrashekar et al. a Near-infrared sensor is used to measure the glucose level of a person which can measure the glucose level without the blood samples from the human body. Another used sensor is BMI sensor which can measure cholesterol level of a person. In this process, a signal is passed through the human body and the sensor waits for the receiving time of the signal on the other side and then the cholesterol level is calculated based on that time. There are two parts - software and hardware. The software application will monitor a persons health by measuring the blood glucose level and cholesterol level of the human body. The hardware kit is made of Infrared sensor and BMI sensor which helps to measure glucose and cholesterol level to monitor a persons health.

In the work of Mr. Li et al. [10] consider some parameters as the vital element of heart condition prediction e.g. (Blood pressure, ECG, SpO2, Heart rate, Pulse Rate, Blood glucose, Blood fat). For intermediate communication Bluetooth and long distance communication Cellular network, Wireless network is used.

In the paper of Mr. Gomez et al. [11] described the statistics of the mortality of patients suffering from different chronic disease. It appears to be that, most of the patients dying from heart failure have been suffering from Overweight 2.6M, Elevated Cholesterol 4.4M, Blood Pressure 7.1M. Therefore, detecting these vital of the patients on a regular basis and sending them for monitoring to a specialist was their main objective. But they described that due to technological limitations these devices are not smaller quite yet. Although some devices e.g. Glucometer, Wrist blood pressure cuff, HRM including electrocardiogram is available today.

III. Methodology

In this section, we have described our proposed method including the list of parameters required in our work. An overview of the entire prototype design and our implementation so far on 3 parameters (heart rate, ECG, cholesterol) are also explained.

A. Parameters

Our main concern is the cardiac issues of patients so, we would need to collect data-set of patients related to cardiac disease. From the previous study done on the field of cardiac disease, there are actually a total of 75 numbers of parameters. Among them, researchers have worked on 14 parameters with Cleveland data-set till now and the result for the 14 parameters have proven to be accurate enough to continue the research on 14 parameters only. Furthermore, we have seen 12 parameters also provides a similar result. So, these 12 parameters mentioned below would be sufficient enough to provide us with an accurate prediction of a patient's cardiac condition. The parameters below given are associated with their respected available sensors.

Parameters through manual input:

1) **Age:** According to this paper, at age 40 the lifetime risk of developing heart disease is one out of two for men and for women it is one out of three. If we consider age as 70 the statistics suggest that it is one out of three for men and for women it is one out of four [12].
2) **Gender:** Heart disease is more seen among the middle-aged people especially it is two to five times more common in men than it is in women [13].
3) **Chest pain type:** Chest pains are the most common symptoms indicating different Cardiovascular disorders. So that's why it is chosen as one of the parameters.

Parameters through IoT devices:

4) **Resting blood pressure:** From the paper of J.Gomez [11] and C. Li et al. [10], we get the numbers from which it appears that most of the patients dying from heart failure have been suffering from Overweight 2.6M 4.4M, Blood Pressure 7.1M. Which leads us choosing RBP (Resting Blood Pressure) as one of the parameters.
5) **Cholesterol:** Elevated cholesterol is one of the major cause of death among people having heart condition said by J. Gomez et al. in [11].
6) **Fasting blood sugar:** Fasting leads to loss of weight and reduction of blood sugar where as it is considered a level of less than 100 mg/dL is normal. Which is why it was chosen as a parameter for generating the cardiac prediction of the patient.
7) **Resting ECG:** ECG stands for Electrocardiograms. ECG is used for detection cardiac arrhythmia [8]. Which is essential because we need to observe the condition of the heart of a patient and detect different anomalies. ECG helps us to do that. Besides we can calculate the hear BPM with ECG.
8) **Max heart rate:** Maximum heart rate is almost equivalent to heart rate although it would help us to observe the heart condition throughout the day.

Future design and implementation using IoT devices:

9) **Exercise included angina:** Angina is a type of chest pain that causes due to the lack of oxygen flow to the heart. It is a symptom of Coronary heart disease.
10) **Old peak:** ST depression induced by exercise relative to rest which is measured by the vertical distance between the iso-electric line and the patient's trace.
11) **Slope:** The slope of the peak exercise ST segment which is a predictive value of coronary disease.
12) **CA:** A number of major vessels colored by fluoroscope which is a predictive value within 0 to 3.

According to the study, these 12 parameters are adequate enough to calculate and predict the overall heart condition of a patient but due to some limitations, we are working on the first 8 parameters and leaving Exercise included angina, Old peak, Slope and CA for future work.

B. Overview of the Design

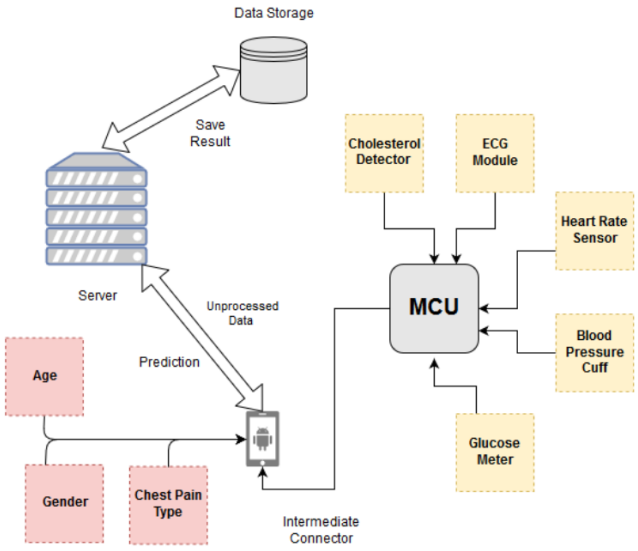

Fig. 1: Block diagram of combined prototype.

This is a simplified block diagram (Fig. 1) of the proposed prototype that we want to implement. We have proposed to use a Micro Controller Unit (MCU). The MCU will be connected to the required hardware sensors and modules. After acquiring all the data from the hardware components it will transmit the data to the smartphone via Bluetooth. The smart phone will also be used to collect the rest 3 parameters. Then all the 8 parameters will be combined and sent to the cloud running the Machine Learning algorithm which will provide the output to the user.

C. Prototype

1) Heart Rate Sensor Module

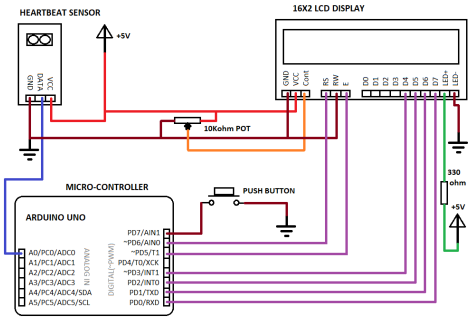

Fig. 2: Circuit diagram of heart rate sensor module.

We have implemented the heart beat sensor to get the maximum heart rate of a patient. The circuit implementation (Fig. 2) is given which provides us the data of heart beat of the subject. Heart Rate Module (LM358), Arduino UNO and LCD display are some of the components which have been used in this implementation.

2) ECG Module

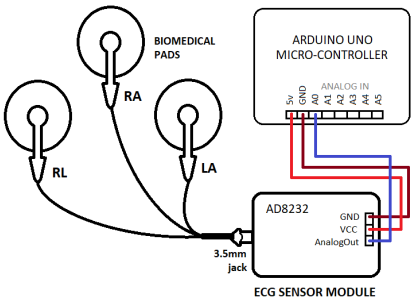

Fig. 3: Circuit diagram of ECG module (AD8232).

We have worked on patient Resting ECG where we used ECG sensor module - AD8232 to get ECG graph and corresponding data. We implemented the module with the existing Arduino UNO micro-controller as it has available peripherals which are required to implement that module (Fig. 3). AD8232 is a single lead ECG module. The sensitive pads are attached to the left hand, right hand and right leg. The output pin of the module is connected to an analog pin of the micro-controller. The output is converted by Arduino then the value is observable in the serial monitor as well as the LCD display.

3) Cholesterol

The non-invasive cholesterol detector (Fig. 4) works by transmitting infrared along the skin of the subject and measuring the received signal reflected back. This circuit contains a photo diode which responses to the infrared light source and converts the optical power into electrical current. The electrical current is then converted into voltage by using a load resistor which varies between 0-5 V [14].

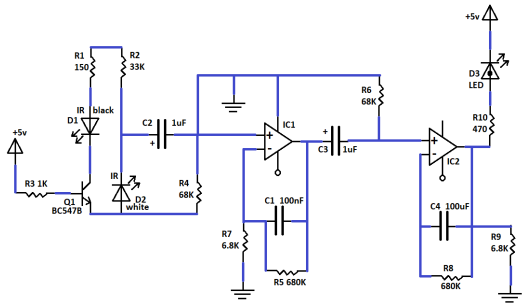

Fig. 4: Block diagram of Near-infrared sensor.

IV. Experimental Results

In this section, we have demonstrated our implemented circuits with the explanation of its working process and visualized the results we have received from different IoT devices.

A. Heart Rate Sensor Module

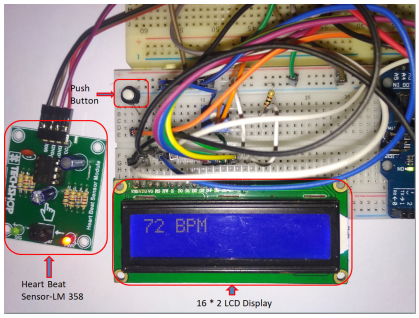

Fig. 5: Implementation of heart rate module sensor (LM358).

Here is the actual implementation of Heart Rate Sensor module (Fig. 5) which is connected to the MCU. The module measures the input for 10 seconds and provides the analog output to the Arduino which is then multiplied with 6 to get the Beats Per Minute (BPM) of the patient.

TABLE I: Sample data of heart rate sensor module

Subject No.	Beats Per Min	Physical Condition
1	66	Normal
2	72	Normal
3	62	Normal
4	90	Increased Respiratory Rate
5	110	Increased Respiratory Rate

Frequent changes in heart rate or regularity of pulse can signify the heart condition of a patient. So in our implemented module, the calculated Beats Per Minute (BPM) of a patient determines whether the physical condition of the patient is normal or the respiratory rate is high. See the table (Table I) providing some sample data of our module for more details.

B. ECG Module

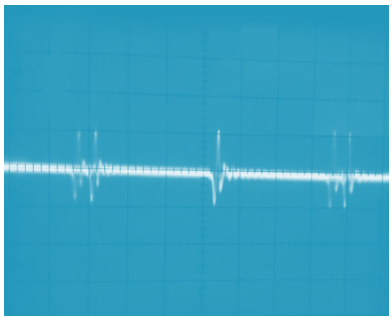

Fig. 6: Output of ECG Module (AD8232).

A single lead ECG module is used which uses 3 electrodes to measure the electrocardiogram. The module is connected in an oscilloscope where we can find the signal displayed above (Fig. 6). We have compared our received signal with real ECG signal by studying a paper [15] where we have found 30% similarities. The main complex part of an ECG signal is the QRS complex (peak value), Q segment and S segment which we have found in our signal output. Still, there are a lot of issues with the ECG signal output on which we are working to improve and find out a much better result.

C. Cholesterol

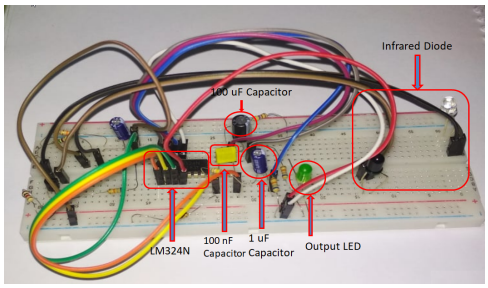

Fig. 7: Circuit diagram of near-infrared sensor.

The near-infrared sensor (Fig. 7) sends a signal through human body and measures cholesterol without taking blood samples [14]. In the basis of each second, we are continuing the detection process for 30 seconds with 30 different samples taken on each of the seconds. Afterwards, we are taking the average value of the voltage drop along the output terminal. We are taking 5.2 mm/L as the standard value of cholesterol in a healthy person.

Correction Factor (X) = 5.2 / Voltage Drop
(For standard value the Correction Factor is = 9.11)

Finally we tuned all the output with respect to the value of (X).

Which provided us the values similar to expectation. Further study and research is needed in this process.

TABLE II: Sample data of cholesterol in near-infrared sensor

Subject No.	Result	Reference	High
1	4.46		
2	4.56		
3	6.65	4-5 mm/L	>6 mm/L
4	5.10		
5	4.74		

According to National Cholesterol Education Program (NCEP), a total cholesterol level of 4-5.17 mmol/L is considered normal and greater than 6 mmol/L is considered high. After testing our implemented module on 5 different subjects we found some data. The table (Table II) shows our findings compared to the biological reference.

D. Combined Prototype: Heart Rate and ECG

The H/W implementation (Fig. 8) we did so far is the combination of Heart Rate Sensor module and AD8232 ECG module where both modules work with a single Arduino UNO microcontroller using 9V DC battery. The required components are given below:

- Arduino UNO x 1
- 16 x 2 LCD Display x 1
- 10K Potentiometer
- 330 Resistor (Optional for LCD back light)
- Push Button
- Heartbeat Sensor Module with Probe (finger based)
- Mini Breadboard
- AD8232 ECG module
- 9V DC battery

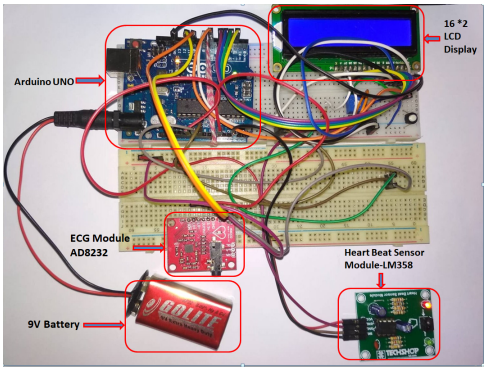

Fig. 8: Combined prototype of Heartbeat sensor module and ECG module.

E. Mobile Application

We have an application (Fig. 9) that is designed to control the complete hardware module. The application is designed for android platform supporting from android 4.2 to upward versions.

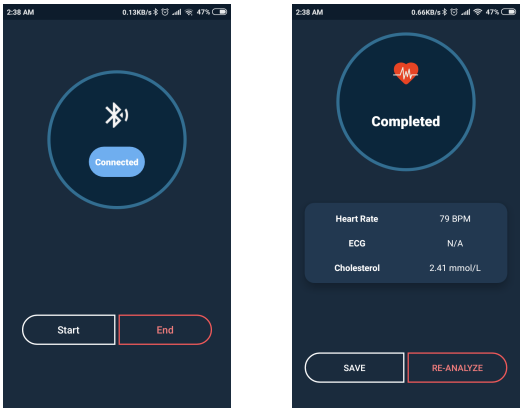

Fig. 9: Sample screen-shots from mobile application

At first, Bluetooth communication has to be made between the hardware module and application. From there we have to start the measurement procedure. When the start button is pressed, initially the heart beat module will be activated and it will calculate the heart rate of a patient for 10 seconds. Final result will be saved for further usage. Secondly, the cholesterol module will start working. Finally, the data generated from the cholesterol module and heart rate module will be combined together and sent to the mobile application and the user will be able to see the final output. Then the user can choose to send the overall output to a cloud based server where it will be saved in a database for further observation in a sequential way. The ECG module is yet to be connected to be operated from the mobile application.

V. Conclusion and Future Work

In this work, we have proposed a method to collect 8 parameters from the human body that are related to the heart using IoT devices to predict and prevent different severe cardiac diseases. The output of heart rate and cholesterol are quite satisfactory, however there is still a lot of room to improve the results.

During the implementation phase, we have faced some difficulties. It was challenging to find the actual IoT devices for the implementation of our required parameters because of the lack of supplies in our country. While implementing the near-infrared sensor to collect cholesterol from human body, receiving the input through a photo diode was tough. After putting much effort, we come up with an electrical current received by the photo diode and converted it into voltage. We tried our device on some subjects and after comparing with the real cholesterol values, we managed to find out the final results of the cholesterol of a patient. Getting the ECG signal from human body was another challenge. The outputs that we were getting at first were not compatible with our needs. As a result, the ECG output signal was very different from the actual one. Finally, we used oscilloscope which provided us the output signal which was very similar to the actual signal. Besides placing the electrodes correctly was quite challenging because it was not obvious which spot would provide the most accurate signal.

In future, we plan to combine all of our modules and circuits to build a complete prototype where after collecting the data, the data will be transferred to a server that run a machine learning algorithm to predict the current cardiac status. The final results are to be visualized through an app.

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