

Heart Disease Detection using ML and ES

(Smart Wearable Health Monitoring System)

Osama M. Abu Zaid

Lecturer in Department of Computer Sciences, Faculty of Computers and Information, Kafrelsheikh University, Egypt

E.mail: osamaabuzaid@yahoo.com and osamaabuzaid@fci.kfs.edu.eg

Adham Aly Mohamed

Department of Computer Sciences, Faculty of Computers and Information, Kafrelsheikh University, Egypt

E.mail: adhamaly80@yahoo.com

Kamel Alaa El-Sehly

Department of Computer Sciences, Faculty of Computers and Information, Kafrelsheikh University, Egypt

E.mail: kelsehly.ke@gmail.com

Mahmoud Mohamed Ossman

Department of Computer Sciences, Faculty of Computers and Information, Kafrelsheikh University, Egypt

E.mail: mahmoudossman348@gmail.com

Mostafa Gamal Mohamed Kamal

Department of Computer Sciences, Faculty of Computers and Information, Kafrelsheikh University, Egypt

E.mail: mostafa.gamal_98@hotmail.com

Marwan Atef Aly

Department of Computer Sciences, Faculty of Computers and Information, Kafrelsheikh University, Egypt

E.mail: marwanatef717@gmail.com

Abstract - This paper proposed a Smart Wearable system that able to monitor the heart beat rate condition of patient. The heart beat rate is detected using photoplethysmogram (PPG). The signal is processed using ATmega32 Microcontroller to determine heart beat rate per minute. Then, it sends the heart rate represented as BPM to Android App Via Bluetooth Communication, Android app sends SMS alert to the mobile phone of medical experts or patient's family member, or their relatives via SMS contains user's current location, Android app calculates daily steps count. Android/Desktop app allow user to check nearest hospitals, cardiac centers, nearest Health centers (GYM) and also user's current location. Android/Desktop app allow user to know if he suffers from heart disease or not by one click which run a machine/Deep learning module that analyze user 's data to detect heart disease.

Keywords - ATmega32Microcontroller,Android,Firestore Cloud, Deep Learning, Machine Learning, Desktop, Java, Python, Neural network, Logistic Regression.

1. INTRODUCTION

Heart rate shows our heart's soundness and assists in determining cardiovascular system health. In the clinical setting, heart rate is monitored under controlled conditions such as measurement of blood, measurement of heart sound, and electrocardiogram (ECG), but it can also be monitored in the home. Our heart pounds to pump oxygen-rich blood to our tissues and bring products of cell waste away from our tissues. The more our heart works to achieve these things, the more we use our muscles, the quicker our heart will pound to pump more blood. A heart rate monitor is essentially a wearable system that takes a snapshot of heartbeats and measures the beats per minute (bpm) so that heart rhythm can be accurately monitored using the details. There are two types of heart monitoring methods to create-electrical and optical methods. The electrical approach has a 1 per cent average error and a \$150.00 average cost. The optical method has a 15 per cent accuracy rating and an average \$20 cost. The average resting human heart rate for adult males is about 70 bpm and for adult females is around 75 bpm. The heart rate varies greatly from person to person depending on fitness, age and genetics. Often enduring athletes have very low rates of heart rest. You can calculate the heart rate by monitoring one's pulse. Pulse calculation may be done using advanced medical tools or simply by pushing one's fingertips against an artery (typically on the wrist or neck). There are several other methods for measuring heart rate, such as Phonocardiogram (PCG), ECG, blood pressure wave shape and pulse meters, but such methods are clinical and costly.

When the coronary arteries are too small, coronary heart disease (CHD), or coronary artery disease, occurs. Coronary arteries are the vessels of the blood which supply the heart with oxygen and blood.

CHD begins to grow as cholesterol builds up, forming plaques on the walls of the arteries. Such plaques cause narrowing of the arteries, which decreases blood flow to the heart. Sometimes a clot will block the flow of blood, causing severe health problems.

Coronary arteries form the network of blood vessels on the heart surface which feed it with oxygen. If these arteries narrow, the heart cannot get enough blood rich in oxygen, particularly during physical activity.

Often CHD can cause heart attack. It is the "most common form of heart disease in the US," where it accounts for over 370,000 deaths per year.

So, our project depends on the CHD Test that needs some attributes such as Gender, Age, BMI, Current Smoker, Cigarettes per day, Total Cholesterol, BPM, Glucose, Diabetes, Prevalent Stroke, Prevalent Hypotensive, Medications, Systolic BP and Diastolic BP.

There is an android app that communicates with the heart rate sensor via the HC-05 Bluetooth module.

The Android / Desktop app has a cloud database (firebase) containing user authentication and user account (image, name, password, etc.).

Android / Desktop transferring the data to a machine learning module to analyze the data and then determine whether or not you will have heart disease. It is achieved by evaluating the dataset with the same information.

The main objective of the project is to create an improved ATmega32 microcontroller-based heart rate monitor using Bluetooth communication to send data wirelessly to your android smartphone that has a machine learning module to be tested, which will enable individuals to use easily anywhere in the hospital, house, workplace, school, etc.

2. WEARABLE DEVICE

We used the built-in feature to build a wearable computer.

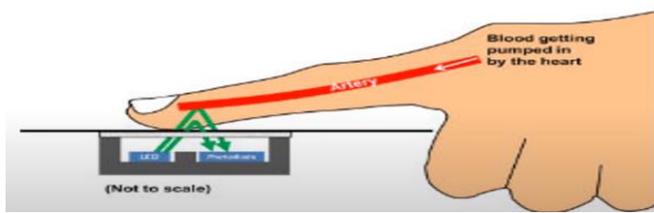
The embedded system is a 'computer system' that consists of a combination of micro processing, memory and input / output Peripheral devices with a specific purpose, with modern embedded systems based mainly on an integrated microcontroller.

Microcontrollers are used in vehicle engine control systems, medical equipment, remote controls.

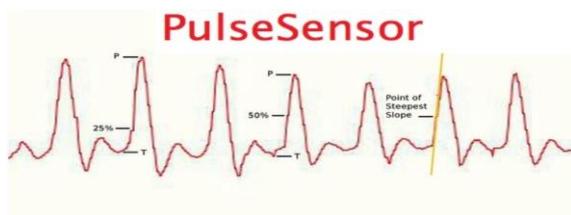
Wearable system is implemented on the basis of atmega32 microcontroller with pulse sensor and other modules, pulse sensor based on PPG technology, PPG (photoplethysmography) sensors use light-based technology to measure the blood flow rate as controlled by the heart's pumping action. Include the Bluetooth module for interacting with the Android app for sending BPM beats per minute and the LCD monitor for viewing BPM on a wearable screen.

Heart beat measurement algorithm is implemented by developing "Pulse Sensor Library" which handles ADC analog to digital converter interfaces and TIMER with microcontrollers:

- ❑ Algorithm start by initializing ADC and TIMER with specific configuration
- ❑ the LED emits light which will fall on the vein directly. The veins will have more blood flow inside them only when the heart is pumping (Systolic), the veins will have little blood flow inside them during (Diastolic) so if we monitor the flow of blood we can monitor the heart beats as well.



- ❑ the light sensor will pick up more lights since they will be reflected by the blood flow.
- ❑ Threshold Value 'T', which is defined to be start point for each beat (25% or 50%) of signal, The Analog and Digital converter (ADC) is start to read an analog signal at T point which represent the received light of blood flow.



- ❑ signal is converted into digital value and applying noise cancellation (dichotic notch which represent closure of the aortic valve)
- ❑ at each 2ms ADC halt the microprocessor for reading from sensor, this operation achieved using an INTERRUPT mechanism
- ❑ calculate average for 10 or more beats to determine our heart beats in minutes

3. ANDROID APP

The android app is developed by JAVA Programming Language.

Our android app represents a friendly main UI which include many features as Daily Heart rate measurement, Step counts, SMS Emergency for heart attack, Coronary heart disease prediction, Medical analyses history and Nearest hospitals maps.

The user has to create an account to grant an access to the android app features.

The info that user has to import is name, email, Phone number, password, birthdate, emergency phone number and profile picture.

The daily steps count, heart rate check and CHD prediction are uploaded to the cloud firebase and the user can retrieve their history data.

Most important used APIs:

- ❑ **Bluetooth:** Android Bluetooth APIs allow applications to link wirelessly to other Bluetooth devices, allowing point-to-point and wireless multipoint functions. An Android application may use the Bluetooth APIs to scan for other Bluetooth devices Request the local Bluetooth adapter for paired Bluetooth devices Transfer data to and from another device.

Used to communicate with the wearable device.

- ❑ **SMS Manager:** handles SMS processes, such as sending SMS messages, email, and PDU(Protocol Data Unit) SMS messages. Used for sending emergency SMS to the emergency phone number that the user registered when the heart rate is in critical case.

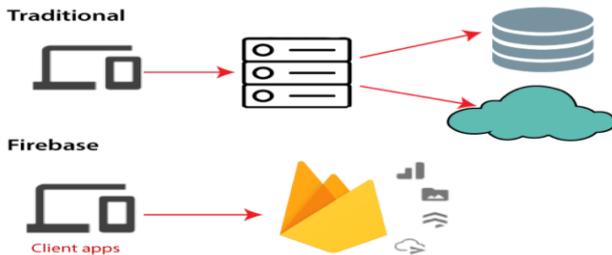
- ❑ **Maps API:** Your app can request the last known location of the user's device using the Google Play location services APIs. You are mainly interested in the actual position of the consumer, which is typically equal to the last known location of the device. Used for locate the nearest health care centers.

- ❑ **PyTorch:** PyTorch Android API Running ML on edge devices is increasing in importance as applications continue to require lower latency. This is also a fundamental item for the defense of privacy strategies, such as federated learning. As of PyTorch 1.3, PyTorch supports the end-to-end workflow from Python to iOS and Android deployment. This is an early, experimental release that we will expand on in a variety of areas in the coming months: to include APIs that cover specific pre-processing and integration tasks required to integrate ML into mobile applications Further performance enhancements and coverage for mobile CPUs and GPUs org.pytorch: PyTorch android is the key dependency of the PyTorch Android API.

Used for sending users health data to the local Pytorch model that predicts whether the user will be a CHD patient in the next 10 years or not to provide a predictive response to the android UI app.

4. FIREBASE

Firestore is a Backend-as-a-Service (BaaS) is a real-time database which allows a list of objects to be stored in a tree format. We can synchronize data between devices.



Authentication

- ❑ Organizing and managing Users.
- ❑ We Support email and password login only.

Real time database

- ❑ The Firebase Real-time database uses data synchronization instead of using HTTP requests.
- ❑ Any user can receive the updates within milliseconds like user's details and history of health and prediction.
- ❑ We have 3 tables:
 - User table that contains needed info.
 - Predict history that contains CHD prediction results.
 - Health history that contain daily steps count and BPM.

Cloud Storage

- ❑ Easy to use through android SDK
- ❑ Enable users to stores files or media data like profile pictures.



5. DESKTOP APP

The desktop app is developed by Python Programming Language.

The desktop app has the same features of Android app except BPM check and steps count.

Our desktop app UI is designed using Tkinter library. It is the standard Python interface to the Tk GUI toolkit:

- ❑ **Window:** In different contexts this term has different meanings, but in general it refers to a rectangular area somewhere on the display screen of the user.
- ❑ **Top Level Window:** A window which exists on the screen independently. This will be designed to the screen manager with the usual frame and controls. It can be pushed around the screen, and can be resized as a rule.
- ❑ **Widget:** The generic term for all of the building blocks in a graphical user interface that make up an application.
- ❑ **Core widgets:** containers: frame, label, top-level, window panel. Buttons: button, button with radiobutton, button with checkbox and button with menu. Widgets for text: label, message, document. Widgets for entry: size, scrollbar, listbox, slider, spinbox, entry (single line), option menu, text (multiline), and canvas (vector and pixel graphics).
- ❑ **Message Box:** Tkinter offers three modules enabling the display of pop-up dialogs, tk.messagebox (confirmation, information, alert and error dialogs), tk.filedialog (single file, multiple file and directory dialogs) and tk.colorchooser (color picker).
- ❑ **Frame:** The Frame widget is the basic organizational unit for complex layouts at Tkinter. A frame is a rectangular region that may have other widgets in it.
- ❑ **Child and parent:** A parent-child relationship is formed when any widget is created. For instance, if you insert a text label inside a frame, the frame is the label parent.

Most important used libraries

- ❑ **Firestore:** Used to connect to our project's cloud firestore database and use their link string properties then initialize authentication, tables, and storage.
- ❑ **Pyrebase:** Used to build new account, log in, authenticate, verify, retrieve account data and update account data, hospitals, and heart centers.
- ❑ **OS:** This module offers a compact way to use functionalities based on the operating system. `open()` if you only want to read or write a file, if you want to modify paths, `os.path` module and see the file input module if you want to read all the lines of all the files on the command line.
- ❑ Used to select a new image profile from a given path.
- ❑ **Urllib.request:** This module defines the functions and classes that help to open URLs.
- ❑ Used in loading the user's profile image of the current user profile image URL link from cloud firestore database.
- ❑ **Pillow:** Python Imaging Collection, and Contributors.
- ❑ The user's profile image from cloud firestore database is used in preview.
- ❑ **Requests:** Makes it extremely easy to send HTTP/1.1 requests. There's no need to add query strings to your URLs manually, or form-encode your POST info. Because of `urllib3`.
- ❑ Used to detect user location when requesting information through an IP address.
- ❑ **Web browser:** a module provides a high-level interface which allows users to view Web-based documents. In certain cases, only calling the module's `open()` function would do the right thing.
- ❑ Used to open a google maps web page on the default user browser for sites like Gyms, Hospitals, and Cardiac Centers nearby.

6. MACHINE LEARNING MODEL

In the section of machine learning, we are getting the inputs(features) from the UI, doing some operations on it then, predicting the output.

So far, this can be done by simple traditional programming, but we are dealing with a massive number of combinations among our data set, so we have to use machine learning in which the machine will find out the best numerical function for predicting the result out of the inputs.

Machine learning is an application of artificial intelligence (AI) that provides systems the ability to automatically learn and improve from experience without being explicitly programmed. Machine learning focuses on the development of computer programs that can access data and use it to learn for themselves.

As our data - on which the machine will train - includes the desired output, so the ML type we will use is Supervised Machine Learning, ML technique is based on three entities:

1. Input data:

First of all, we are collecting our data on which the model will train and it has to be accurate, trusted and balanced, so we got it from Framingham university which is specialized on the researches of heart diseases

The second phase is to do data preprocessing for making the data readable and understandable for the machine module just like cleaning the data for making it null-free

The last phase is to do some data transformation like normalizing or scaling (a simple function for overcoming skewed data)

2. Finding relations and patterns:

Machine learning has several algorithms that can be used for finding the relations among the data, it can be chosen simply based on the type of results (classification or regression), so we chose the Logistic Regression as the best algorithm for our result type which will be a fraction that indicating the user situation

3. Output (optimum Model):

Training the Linear Regression model will make it able to generate the best numeric function which will be used to predict the result, this function is characterized by being converged for the values of 0 or 1 which indicate the user situation with an accuracy of 88%

7. DEEP LEARNING MODEL

Deep Learning that subfield of machine learning was important in our project for helping embedded system to think and the android application to predict if the user will have a heart attack in the next ten years, we used specifically “Pytorch” library because it’s an easy library to learn and build a model and it’s combatable with android applications in connecting so it’s the best choice from deep learning libraries, we used “Neural Network” to help us in improving our performance from the relations and features extraction that increases the features of our data by find new relations between them all of that get the best pattern and combination of our data to predict the results.

We split the phases of our module into three phases:

First phase is Data Preprocessing that we clean the data from any invalid data or null values and drop them from the data, then we normalize the data because if it’s skewed we minimize the difference between value and it’s increase the easiest way in dealing with the data finally we use one-hot-encoding dummies that help us with categorical data of being indicated as a value we transfer it into vectors so the module indicate with it as a category.

Second phase of our module is splitting the data, deep learning module based on training in a part of the data given then find a relation between them and the desired feature then we give the rest part of the data to test its accuracy of prediction, so we split our data into 75% of training data and 25% testing data that the module can train in the large side to get the correct combination.

Third phase of our data is creating the neural network module, neural module act as the Nervous system of the human brain it’s consists of layers the first layer called input layer and the last one called output layer and the middle ones called hidden layers and each layer has a number of neurons that connected with each other’s to generate a new neurons in a new hidden layer after passing into an activation function that turn the result into the final form, in our module we used a one input layer with the number of our features as neurons and two hidden layers each one have 15 neurons and a one output layer have 2 neurons that 1 for the one who will have the heart attack, 0 for the one will haven’t, also we used “RELU” as activation function at every because it’s the best activation function that result a best result.

After all of that we pass the data into our module to train and get a result and it’s got us accuracy equal to 89,8% so it’s a great result in predicting so that deep learning helped us so much.

8. CONCLUSION

Wearable devices are now used for a wide range of health observation purposes. One of the most important elements of data collection is the sensor. In recent years, with improvements in semiconductor technology, the sensors have made a full range of parameters closer to realization.

Wearable devices are becoming more and more popular in various fields, from sport and fitness to health surveillance. In particular, due to the increasing number of elderly people worldwide, wearable devices are becoming increasingly important for long-term health surveillance.

The most important criteria in this study were the possibility of using a device in the real world, performance, efficiency and power consumption. In addition, we have considered the price of each device.

Two key features are provided to the user in this project.

First, an Android app that communicates with a Wearable device that measures heart rate through Bluetooth communication. While the BPM of the user becomes unstable, the app sends SMS alerts to a mobile phone belonging to a medical expert or a patient's family member, or its relatives via SMS contain the current location and patient status of the user.

Second, Android / Desktop that lets users know if they have heart disease or not by one click running a machine learning module that analyzes user data to detect heart disease.

Other features include calculating daily steps and checking the nearest hospitals, cardiac centers, nearest health centers (GYMs) and the current location of users.

We used java programming language, python programming language and C-programming language to implement this.

C-the programming language used to develop Embedded Devices using the Embedded C version with Eclipse IDE that facilitates the development of the process.

Java programming is used to develop Android apps with Android Studio3 that provide a huge number of libraries.

Python programming language used to develop the Desktop app with the Anaconda Jupyter notebook. The Machine Learning and Deep Learning models, too. They've all used a lot of important libraries.

The project is determined by the merits of the system offered to the user. The merits of the project are as follows:

- Wearable device for calculation of heart rate
- Real-time heart rate monitor
- Actual daily steps count

- Emergency SMS with current location
- Prediction of high accuracy CHD
- Real time database, storage and authentication on Firebase Cloud Server
- Nearest Hospital, Cardiac Center and Health Care Gyms.
- Provide the user with his medical history in order to monitor his or her health.

14. <https://docs.python.org/2/library/webbrowser.html>
15. <https://docs.python.org/3/library/os.html>
16. <https://docs.python.org/3/library/pickle.html>
17. <https://pillow.readthedocs.io/en/stable/>
18. <https://www.medicalnewstoday.com/articles/184130>
19. <https://pypi.org/project/firebase/>

9. FUTURE WORK

There are some limitations to the current system that can be addressed as a future development:

1. The Embedded Device Board (ATmega32) will be reduced in size by printing another PCB board using the (ATmega8) microcontroller.
2. Adding other sensors for wearable devices such as (temperature sensor, blood pressure sensor)
3. Enhance the body of the wearable device.
4. Enhance user interface to make it more user-friendly.
5. Adding more features to the app.
6. Improve the accuracy of the prediction model.

REFERENCES

1. AVR Microcontroller and Embedded Systems: Using Assembly and C (Pearson Custom Electronics Technology) 1st Edition
2. Python Machine Learning with scikit-learn and TensorFlow (Second Edition)
3. Logistic Regression in Python (Tutorialspoint)
4. Deep Learning with PyTorch (A practical approach to building neural network models using PyTorch)
5. Python GUI Programming Cookbook Second Edition (Develop beautiful and powerful GUIs using the Python programming language)
6. <https://pdf1.alldatasheet.com/datasheet-pdf/view/77378/ATMEL/ATMEGA32.html>
7. <https://developer.android.com/guide>
8. <https://firebase.google.com/docs/android/setup>
9. <https://www.tutorialspoint.com/cprogramming/index.htm>
10. <https://www.kaggle.com/neisha/heart-disease-prediction-using-logistic-regression>
11. https://scikit-learn.org/stable/modules/generated/sklearn.linear_model.LogisticRegression.html
12. <https://docs.python.org/3/library/tkinter.html>
13. <https://www.microchip.com/wwwproducts/en/ATmega32>