ASHESI UNIVERSITY

AN IOT-BASED REMOTE HEALTH MONITORING SYSTEM FOR REMOTE LOCATIONS IN GHANA

APPLIED PROJECT

B.Sc. Computer Science

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2020

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APPLIED PROJECT

Applied Project submitted to the Department of Computer Science, Ashesi University in partial fulfilment of the requirements for the award of Bachelor of Science degree in Computer Science.

Albert Essilfie

2020

DECLARATION

I hereby declare that this Applied Project is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature:

………

Candidate's Name:

………

Date:

………

I hereby declare that preparation and presentation of this Applied Project were supervised in accordance with the guidelines on supervision of Applied Project laid down by Ashesi University.

Supervisor's Signature:

………

Supervisor's Name:

………

Date:

………

Acknowledgements

I would like to express my deepest appreciation to my supervisor, whose encouragement and academic advice helped me undertake this project. And to my dear parents whose love and support has guided me throughout my time in Ashesi. God Bless you all.

Abstract

Life is one of the most valuable things to mankind. The mere fact of losing one's life or the life of a loved one is an unbearable experience. The health of each individual is very important. The risk of inappropriate access to proper healthcare poses a serious risk to an individual's life. Access to healthcare today in our urban areas has been improved greatly by our health industry. But what about our distant members in rural areas? Can they boast of the same access to health care or attention? Valuable lives are being lost daily due to the lack of access to essential healthcare in rural areas. With the rate at with technology is evolving, accessing remote areas should be made relatively easy. This capstone report highlights focuses on the problem of the inability for individuals to have access to medical attention due to the problem of long distances particularly in the rural areas. In this capstone report, I attempt to solve the problem of distant healthcare by using the technology of internet of things and machine learning to help provide some level of medical attention to individuals in rural areas. At the end of this capstone report, patient's health are monitored using their vitals. Results of patient's vital signs are posted to a remote server for which a medical facility has access to for further analysis from which feedback and attention can be given to the patient without the presence of the patient at the hospital.

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Chapter 1: Introduction

Technology improves our lives. Various consumer technologies have made it possible for us to interact and explore our world in smarter ways. The pervasiveness and ubiquity of present-day technology are responsible for the fact that today, we possess much computing power in our devices than computers did some years ago and has enabled individuals to improve the way they work, travel personally, interact with others among others.

1.1 Background

The health of an individual is essential and can be fatal if not given the necessary attention. Quick and efficient access to health care services is critical in determining the health status of a person: a loved one. The Government of Ghana has made efforts to provide sufficient health facilities to the nation, which has made significant development in the health industry as has affected the lives of many individuals across the country. Though the government's efforts to improve the health system in Ghana are praiseworthy, some aspects still lack adequate attention mainly access to health care services in rural areas. As a result, a significant proportion of communities within rural areas in Ghana have poor access to essential health services [2]. 4% of communities within the WA West district, for example, have high physical access to District Hospital [1]. A significant barrier in reduced access to health services in the rural areas is poor conditions of roads.

1.2 Related work

Technology is ever-changing in modern-day society. From the invention of the first computer, the 1950's networks have come a long way in helping us store large sums of data which people have limited time, attention and accuracy for capturing data about the real world [4]. In our world today, almost every device thrives on data. The dependency on data has given birth to what we call the internet of things, where every device is connected, and data flows in synchronization within these connected devices. Below are examples that make use of the internet of things and other technology:

Wearable IoT Enabled Real-Time Health Monitoring System

The wearable IOT Enabled real-time health monitoring system, WISE for short is designed based on the body area sensor network (BASN) framework in support for real-time monitoring [7]. The system makes use of the pulse sensor, temperature sensor and accelerometer in monitoring the health of the person in possession of the device. The system makes use of the IoT cloud to post data to a server for remote access by users using a mobile device such as mobile phones personal computer and the like. The user component aims to provide a convenient interface for user access. Still, issues concerning service delivery must be addressed as well as adaptive, personalized services for both patients and their doctors [7].

Blood Pressure Management Using Arduino

This article provides a simple means to calculate and monitor blood pressure using the heart rate sensor connected to an Arduino microcontroller. The Mechanism of this system is dependent on the voltage supply to the Arduino, which requires a 5V initial power supply [6]. The blood pressure is calculated as the product of cardiac output and the resistance and then displayed on an LCD. The result of this system is to show the resulting blood pressure calculated. The system can be improved further to enhance its features in terms of adding the technology of IoT to store and retrieve historical data for further analysis.

Apple Watch

The Apple Watch is a smartwatch that performs other functionalities in addition to is the primary function, that is, to display the time. The Apple smartwatch is wearable technology. A notable feature of the Apple watch is its fitness functionality. Some sensors embedded in this wearable smart device include a heartrate sensor and an accelerometer [8]. The heartrate sensor keeps track of beats per minute by monitoring the blood flow in the wrist [8]. The watch is capable of generating an electrocardiogram which can be sent to a health facility for analysis when desired by the user. The embedded accelerometer in the device keeps track of body movement, which is translated into fitness information to monitor a person's health [8]. All health records recorded by the smartwatch are sent to a medical facility for further analysis at the user's discretion. This device makes use of the concept of IoT the use of wearable sensors and remote access to data from medical devices. It hence serves as a guide to this project to mimic the real-time distribution of data and sensor readings.

1.3 Project Objective

Within the past decade [2010 - 2020]. Primary health care provided to rural areas has been at its' barest minimum. Though the government continues to make efforts to provide these services to rural areas. The process is moving at a slow pace, and in some cases, some solutions provided end up failing. For example, in the Pru district where the provision of Village Health Workers to the District failed once the project was scaled up [2]. The slow development in the health sector should not be the reason to which individuals' health is at risk. This risk in the worst case may lead to loss of lives to which the families of the deceased is not compensated.

This project aims to equip individuals (health patients) in remote rural areas who do not have quick and easy access to health facilities and services. A simple healthcare device which monitors their vitals and receives medical attention and advice from doctors and health practitioners registered on the platform will be the solution to this problem.

1.4 End Product Functionality

The end product will be a functioning prototype of the health monitoring device consisting of three primary sensors to monitor patient vitals: Heart rate, body temperature and blood pressure. The device will take readings from the patient concerning the sensors. A health practitioner will then be able to view patient data from a platform created for health practitioners. Based on the analysis, diagnostics are sent to the patient. In any case, whereby the patient requires quick attention, the closest health facility attends to the patient for medical treatment.

Chapter 2: Requirement Gathering

To obtain a better understanding of healthcare status in rural areas, we narrow down the focus group to healthcare access in the Pru district.

Major issue contributing to the poor to healthcare involves inadequate health facilities, a long distance from individual homes to health care centres, and lack sufficient and efficient transportation systems, insufficient health personnel and inability to afford the cost of health services [2]. Transportation is very critical in accessing health services. The Ghana government has carried out projects to help curb the transportation issue regarding access to quality health care amount the rural dwellers; unfortunately, their efforts have been to no avail. One project involved hiring village health workers (VHW) to provide health services in the rural areas with reasonably priced services which were successful in its early stages but did not survive once the process was scaled up [2]. Challenges about the problem involved resource, training, issues of monitoring and supervision [2]. Considering HealthCare access in the Pru District, the area consists of ten (10) health care facilities. This includes a single mission hospital located in the district capital, Yeji. The primary health challenge in the Pru district lies in its quantitative health needs. Of the ten healthcare facilities in the District, the District consists of only four doctors putting the doctor-patient ratio to 1:30854 as compared to the national rate of 1:9251 which indicates an improper distribution of medical attention to respective patients in the District. This implies that doctors in the Pru district have an overwhelming additional number of 29,929 patient per doctor to the standard of 925 patients per doctor.

Concerning distance, 32.3% of households within the District are within proximity to the nearest health Centre as opposed to the regional average of 53.85% [2]. In analyzing the 32.3% of households that are within proximity. Research shows that the percentage of homes within reach of the nearest health facility occurs around the capital; thus, around Yeji. Moving towards the localities of the Pru district, thus away from the capital, 92.7%1 of the households are subject to receiving health care from traditional healers and have little or no access to professional treatment to proximity issues.

Another concern regarding health care service in the Pru District involves transportation cost. Due to high transportation cost, individuals in the rural area forced to make visits to the medical Centre's only when health conditions have reached a high peak. The means of transportation in itself is a problem in the District. They are limited to using services such as the tricycle operator, a boat or motorcyclist popularly known as "Ocada." Estimates show that the cost of transportation in the rural area is about GH₵15.001, which is expensive to the individual who earns an average annual income of GH₵3,655.001.

Highlights of the situation concerning access to health services in the Pru district involve lack of reliable means of transport, high doctor-patient ratio and senior transportation cost. Hence the questions that may arise are: how do we reduce the patient-doctor rate? How can ensure that rural dwellers can have access to professional health care services even though they face challenges with distance. Can we bring the hospital to them instead of taking them to the hospital? How do we ensure transportation cost convenience or provide a safer and better means of transportation to the rural dwellers?

2.1 Common Diseases in the District

To influence the outcome of the product, a better understanding of significant diseases in the area is needed. Common illnesses found among the inhabitants are Malaria, diabetes and hypertension [2]. Most individuals are perceived to have contracted these diseases but do not know of it due to the lack of diagnostics as a result of the challenges faced in accessing health facilities.

2.2 Procedure for Requirement Gathering

Surveys conducted on the said area provided relevant information for the analysis of this paper and guided the decision towards the end product.

Sensor Details:

- Pulse/Heartrate Sensor: Monitors the patient's heart beats per minute.
- Blood Pressure Sensor: Monitors and keeps track of the patient's blood pressure.
- Body Temperature Sensor: Monitors the body temperature of the patient.

2.3 Health Care Component

Registered Health Care Centres will have access to patient profiles and medical reports, including sensor readings to assist in diagnosing cases and handling emergencies.

The issue of transportation cost may not be directly addressed in this project. Still, the use of a device that can help monitor patients health vitals from a remote location indirectly reduces cost. This is because the number of trips made to the hospital for regular check-up is reduced due to the presence of the system.

An emergency response unit may be ideal to benefit a patient in an extreme case. The emergency unit works by using sensors to detect values that may be crucial to the patients' health, in the case whereby an emergency is detected, the nearest hospital is contacted to reach out to the patient. This will be done by dispatching an ambulance to the patient residence. In cases where dispatching an ambulance is not feasible, the patient may receive first aid guidance from the doctors via the system until aid arrives.

2.4 Machine Learning Component

To solve the issue of the unrealistic distribution of the doctor patient ratio, a machine learning component will be added to the system which serves as the main contribution to this project. The algorithm takes care of predicting the presence of underlying heart diseases and providing respective diagnostics while monitoring the patient. Any prediction and diagnosis carried out by the algorithm are still forwarded to a professional medical facility for verification purposes. This helps the algorithm learn and increase its efficiency, hence reducing the margin of error. The verification helps doctors keep track of the status of the patient in case of any wrong outputs obtained from the algorithm.

2.5 Transportation Cost

Concerning transportation cost, the main aim is to ensure that cost of transportation is not a burden to individuals who desire to access the health Centres. With the aid of the machine learning algorithm, frequent trips to the health facilities are reduced significantly. In any case a patient is needed at the Health Centre, he or she is notified and is allowed to make payment based on instalments if the patient cannot make payment immediately. Thus, the health Centre in charge of the patient may take up the responsibility of providing means of transport for the patient if the patient accepts the offer. And hence payments made accordingly.

2.6 User Identification

A typical user for this system involves the following:

- An individual in a remote area with health symptoms that will require check-up from a professional medical institution.
- A patient who has undergone surgery and requires frequent monitoring to avoid emergencies.
- Individuals who will require immediate attention from doctors based on symptoms exhibited.

Chapter 3: High Level Systems Overview and Architecture

3.1 Main Device Connectivity

Figure 1. Shows the main connection in the device module. Three Arduino compatible sensors (Blood Pressure, Pulse and Temperature) connected to the Arduino microcontroller. The microcontroller connects to the internet via Wi-Fi module to post the result to the central server for results to be viewed on a desktop or mobile

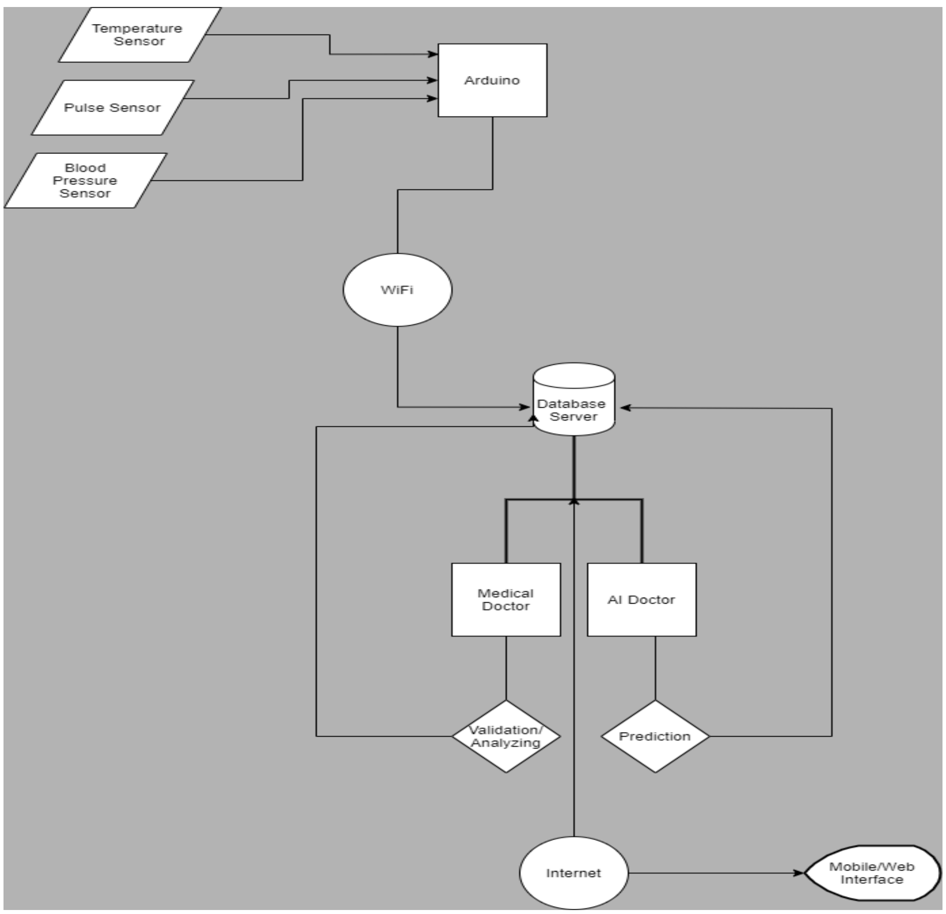


Figure 1 Device Connectivity

3.2 System Design

The main contribution of this work is the Machine learning component attached to the system, which will serve the purpose of monitoring the patient's vitals to detect possible occurrences of a heart disease that may occur. Upon detection, the component carries out necessary precautions to ensure the patient safety and reduce the risk of any potential fatal that may occur to the patient.

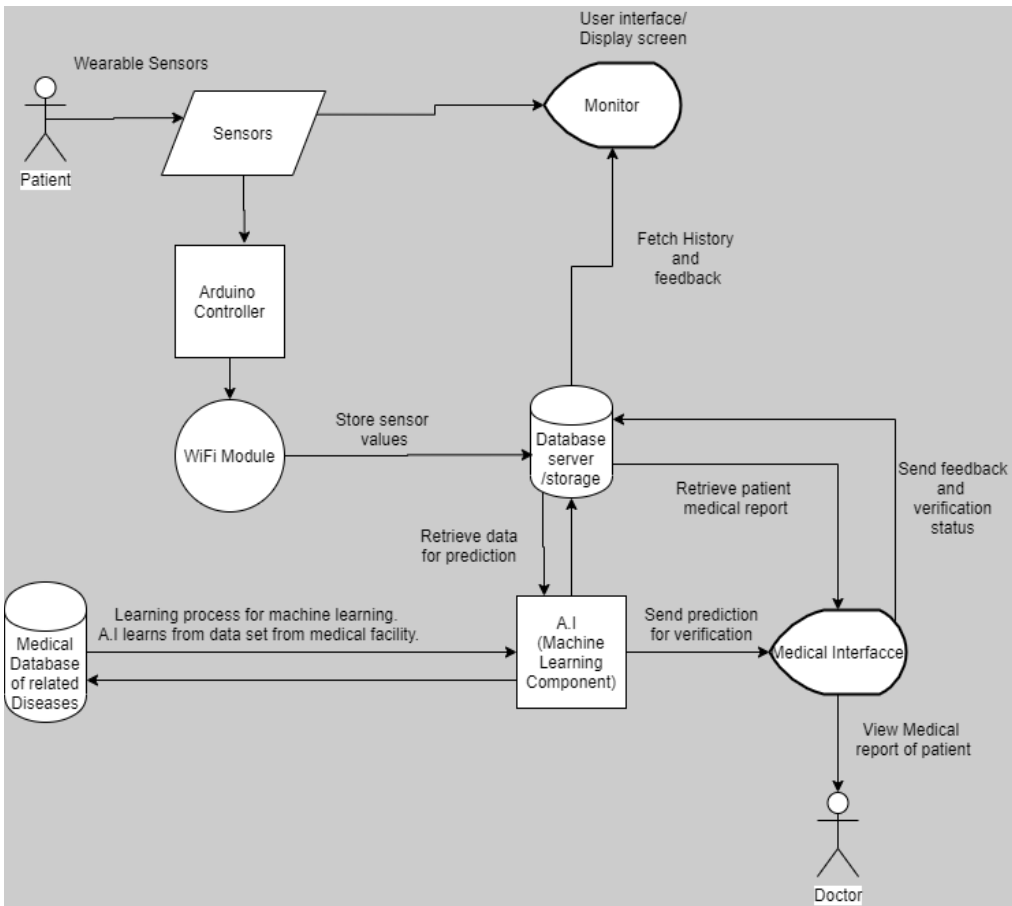


Figure 2 System Design

3.3 Key Modules and Layers in the Implementation

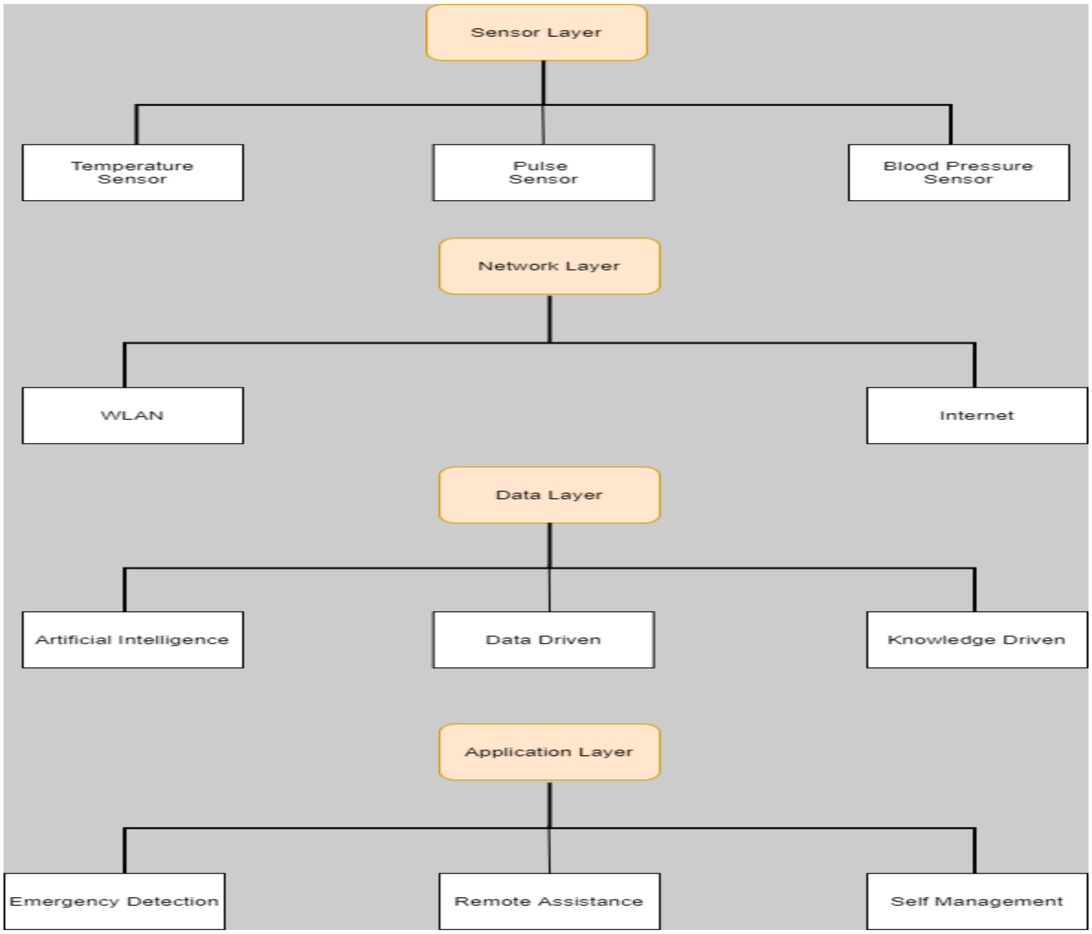


Figure 3 Key Modules

Figure 3 shows the key modules and layers of the system [7]. The sensor Layer, Network Layer, Data layer, and the Application layer.

The sensor layer is responsible for reading input data from an individual. The Network layer is responsible for connecting the device to the internet to facilitate data transfer from one endpoint to another. The Data Layer is responsible for record-keeping, and data analysis and prediction by the machine learning algorithm including diagnostics which is handled both knowledge-driven (human interaction: Doctor) and by the algorithm through its learning ability.

The final layer is the application layer which is responsible for user interaction and other functionalities such as emergency dispatch features, chat features and the like.

Chapter 4: Implementation

The entire system consists of four main components of which are:

- Physical Device
- Machine Learning Component
- User Interface
- Medical Health Database

This chapter looks into detail the various implementations of each part and the functionality of the system as a unit.

4.1 Physical Device

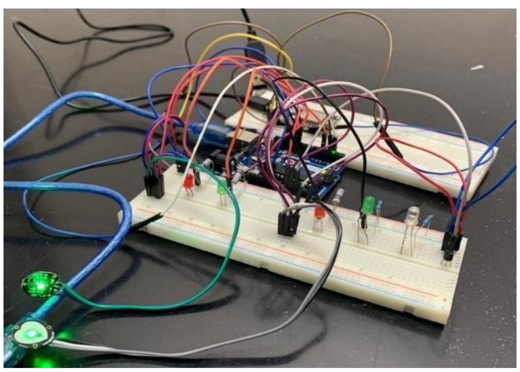


Figure 4 physical device

The physical device consists of the following components:

Component	Unit
Pulse Sensor	2
LED	4
LM35 Temperature Sensor	1
Resistor (240 ohms)	4
Jumper Wires	
Arduino Uno	1

NodeMCU (ESP8266) WIFI Module	1

Tool(s) used: Arduino IDE

Circuit for Physical Connection

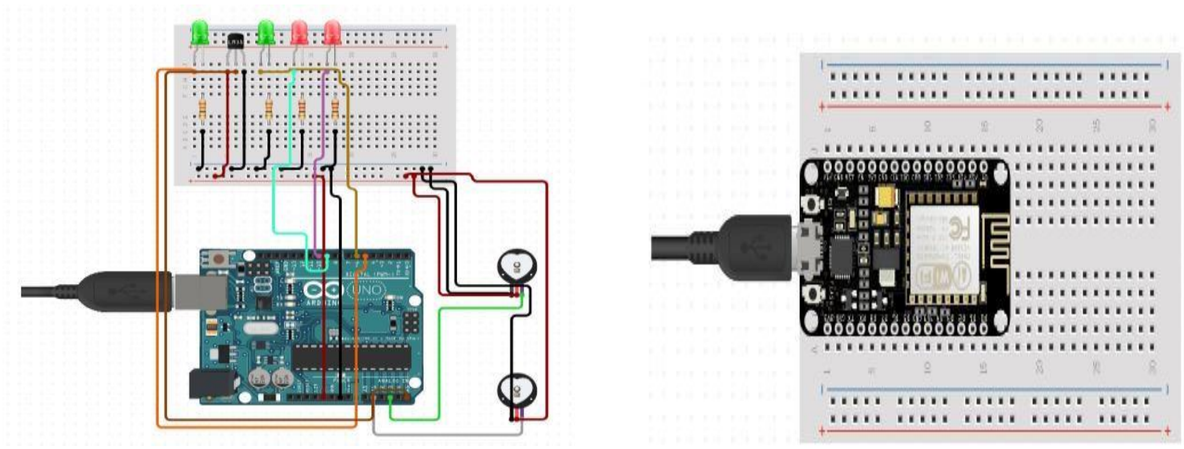


Figure 5 Circuit

The physical device aims to record body vitals of a patient, namely: blood pressure, body temperature and beats per minute (pulse).

Pulse sensors record the number of beats per minute of an individual when placed on the skin surface of an individual. The heart pumps blood through the veins, which causes a variable change in the volume of blood in the capillary blood vessels, which can be sensed by the light reflected by the pulse sensor. The volume of the blood in the capillary blood vessel will be high during a heartbeat; hence low reflected light rays and vice versa. To obtain better output results, this project utilizes the operation of two pulse sensors to observe data recorded.

Each pulse sensor works in hand with two LEDs (Red (x1) and Green (x1) each) to monitor the regulation or the pulse. The Red LED blinks on sensing a Pulse, and the Green LED, in turn, has an animated effect of fading in and out in response to the pulse.

The LM35 is the sensor used to measure boy temperature of the individual. The temperature is measured when the individual makes physical contact with the sensor using the fingers. The body temperature is then read and calculated in degrees Celsius and recorded for analysis.

There is no physical sensor in the circuit to record the patient’s blood pressure. Nonetheless, blood pressure can be calculated using the pulse sensor. This gives a fairly good estimate of the patient’s blood pressure though it is not 100% accurate. Therefore when the heart rate per minute is calculated, the cardiac output is then calculated followed by the resistance and hence the blood pressure [6].

The Arduino UNO serves as the main controller that connects each sensor and LED and other components together [7]. The main function of the NodeMCU (ESP8266) within the circuit is for data transfer to a server via a wireless medium. Though the NodeMCU may also serve as a microcontroller, it has only one port for analogue input, hence making it difficult to accommodate multiple analogue sensors for which this project involves (pulse sensor (x2), temperature sensor (x1)) hence the need for both microcontrollers.

Data is transferred to the NodeMCU by the Arduino using serial communication before the data is sent over the wireless medium to the database.

Libraries Used in Code development:

- PulseSensorPlayground
- ESP8266WiFi Library
- ArduinoJson

4.2 Machine Learning Component

The machine learning component serves as a virtual doctor to registered patients of a medical facility. The system is designed to help reduce the patient to doctor ratio, which measured as 1:30854 in the Pru district [2].

The virtual doctor component monitors the vitals data in the database (body temperature, Blood Pressure and Beats per minute) recorded from the physical component and tries to predict potential heart disease that would be harmful to the patient's health. The component then works to find the shortest possible emergency health team to respond to the patient if the situation is critical or otherwise supplies a form of first aid to serve as a self-treatment for the short-term. In contrast, the health facility monitors the status of the patient for medical attention to sort the shortest possible time.

The machine learning component is designed using a neural network. The network is trained using a heart disease dataset obtained from the Kaggle Repository, a ".csv" file containing various attributes that result in a patient's potential to have a heart disease occurrence. Below shows the neural network definition for the heart disease module. This particular dataset is used due to no access to actual data recorded in an African hospital with similar results. Most Local hospitals do not publish their health detailed health records of patients.

4.3 Prediction Process

<u>Heart Diseases</u>

Heart diseases are defects caused by the human heart. Some example of heart diseases includes hypertensive heart disease, congenital heart disease and inflammatory heart disease. Major causes of heart diseases are associated with unhealthy diets, harmful use of alcohol and physical inactivity [5]. These conditions can be fatal the life of an individual if not treated properly and early.

Heart Disease Data Set

The data set used in this capstone report is the Heart Disease UCI obtained from the Kaggle repository and can be obtained from *https://archive.ics.uci.edu/ml/datasets/Heart+Disease*.

Data Set Description

The Heart Disease data set consist of 76 attributes, but published experiment on this dataset refer to using only fourteen (14) of the seventy-six (76) attributes. All names and social security numbers of patients are not included in the dataset. Instead of actual names and social security number of the persons associated with the dataset, dummy values have been used to represent the said persons.

This capstone report focuses on predicting the presence of heart disease in individuals, particularly in the Pru District, found in Ghana, Africa. The dataset obtained does not include values of African descent. Hence predicted values might be skewed towards European characteristics and not much characteristics of an African. This data set was used because data sets of this kind are not available for machine learning research purposes as of the time of this capstone report.

The target of the data set has two classifications:

- Heart Disease (indicating the presence of heart disease)
- No Heart Disease (indicating no presence of heart disease)

Obtaining significant data from the Data Set

To begin, I first identify the parameter in the dataset that shows a significant relationship with the target (heart disease). This is done by studying the correlation among the attributes.

Graph Showing the Correlation between the various factors and the target

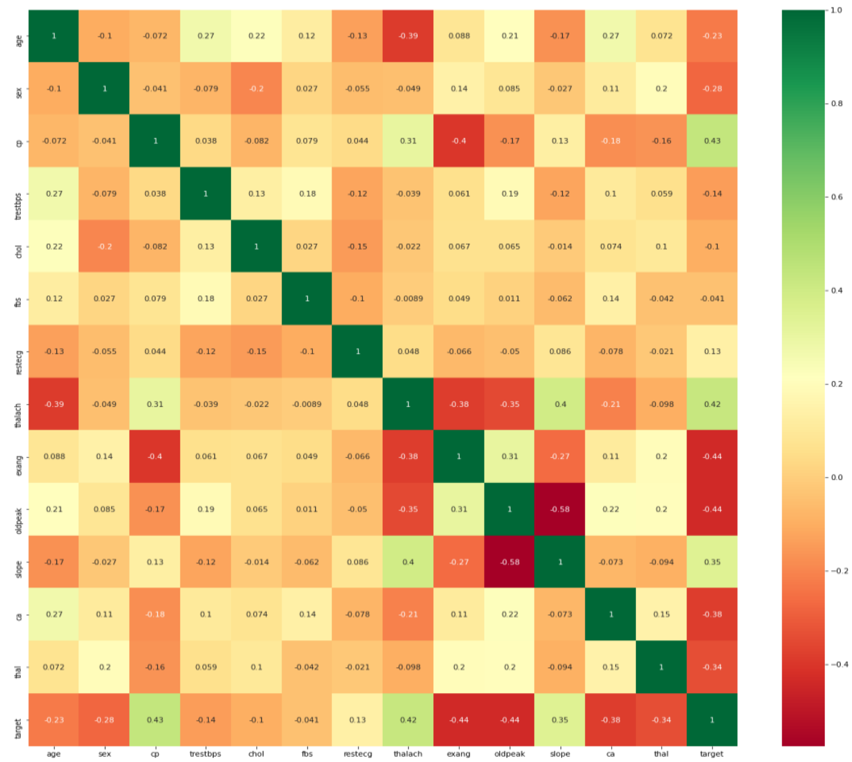


Figure 6 correlation

Chest pain (cp), heartrate (thalach), restecg (rest electrocardiograph) and the slope show a positive correlation to the target. Hence they play significant roles in determining the presence of heart disease in an individual. The other variables depict a negative relationship with the target. Factors for prediction for this paper were chosen based on the availability of similar information to the dataset. Hence the heart rate, blood pressure, restecg, Age and Sex were chosen as contributory factors for prediction in this paper. Age, Sex and blood pressure (tresbps) all depict negative correlation with the target. This does not imply that they cannot be used in the prediction. If the value decreases for the negative correlation, the heart disease prediction may be quite high.

Selected Attributes from Dataset

Now that the parameters needed for training and testing have been obtained, the attributes that play less significant roles in determining the target are dropped. Hence the table below.

Name	**Type**	**Description**
Age	Continuous	Age in years
Sex	Discrete	1 = male 0 = female
Trestbps	Continuous	Resting blood pressure (mm Hg)
Restesg	Discrete	Resting Electrocardiographic: 0 = normal 1 = ST-T wave abnormality 2 = probable or define left ventricular hypertrophy by Estes'criteria
Thalach	Continuous	Maximum heart rate achieved.

Neural Network Class Definition

```
class Heart_diseaseNN(nn.Module):

    def __init__(self):
        super(Heart_diseaseNN,self).__init__()
        self.h1 = nn.Linear(5,350)
        self.h2 = nn.Linear(350,350)
        self.output = nn.Linear(350,2)
    def forward(self,x):
        x = F.relu(self.h1(x))
        x = F.relu(self.h2(x))
        return self.output(x)
```

Figure 7 Network Class

Tool Used:

- Jupyter Notebook
- Pytorch
- Sklearn
- Pandas

In the class definition, the neural network comprises of two hidden layers (h1 and h2) and an output layer that gives two outputs (0 or 1).

The first hidden layer takes a batch size of 5 and then gives out features of 350. The second hidden layer in turn also takes a batch size of 350 and returns an out feature of 350 outputs. Finally, the output layer takes the batch size of 350 inputs and outputs two outputs.

Obtaining the batch size values and output sizes is derived from the shape of the trained X tensor that will be inputted into the neural network.

Hence the trained data consist of 615 results of 5 inputs for the neural size allocation in the "heart_diseaseNN" class.

```
X_train.shape
Out[6]:
(615, 5)
```

Figure 8 Shape of Trained data

ReLU Function

The rectified linear activation unit, ReLU for short is used to use the stochastic gradient descent and backpropagation errors to train the neural network to facilitate the learning of the complex relationships in the data.

4.4 Medical Health Database Tables

The Medical Database is designed to store information of every entity involved in contributing to the health analysis of a patient. Below is a brief summary of the tables in the database.

- Patient: Patients demographics
- Doctor: Doctor details, including an associated hospital.
- Vitals: Record for vitals recorded per patient.
- Assignment: Doctor-Patient assignments.
- Patient_Record: Record of patient’s diagnostics.
- Diagnostics: Diagnostics details and guidelines.
- Hospital: Hospital details.
- Disease: disease type and information.

Entity Relationship Diagram

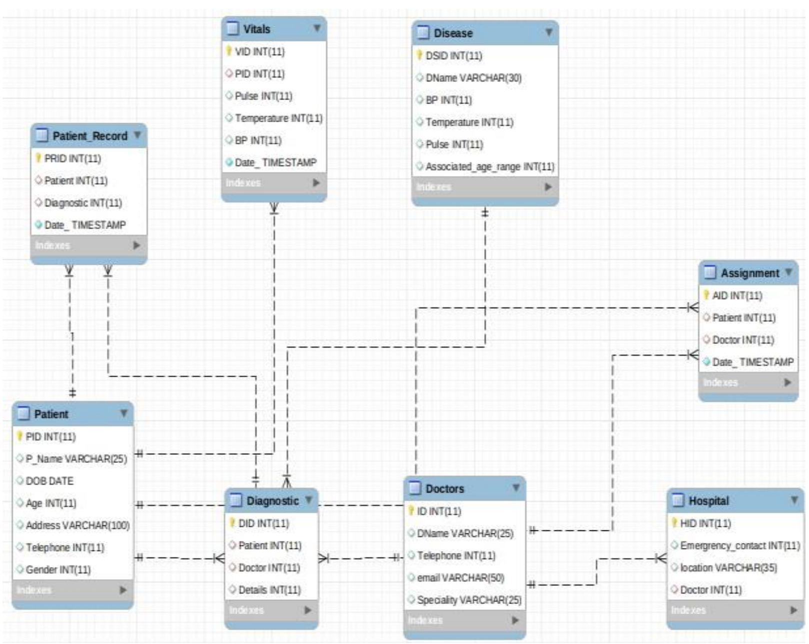


Figure 9 EER Diagram

Each table in the database has a relationship with other tables that exist in the database. Below is a summary of the two main tables and their relationships:

Table Relationships Summary

Patient Table: The patient table contains the demographics of the patient and has the following relationships with other tables:

1. **One to many (Patient table)**
   - Patient - Assignment: One patient can be assigned to many doctors.
   - Patient - Diagnostic: One patient may be diagnosed many times.
   - Patient - Patient_Record: One patient has many records
   - Patient – Vitals: One patient has many instances of recorded vitals.

Doctor: The Doctor table contains the essential details of a Doctor and has the following relationships with the following tables:

1. **One to Many (Doctor Table)**
   - Doctor-Assignment: One Doctor has many assignments.
   - Doctor-Diagnostic: One doctor can diagnose many patients.
2. **One to One (Doctor Table)**
   - One doctor is registered to one hospital.

4.5 Sample Data in Database

Patient Table

PID	P_Name	DOB	Age	Address	Telephone	Gender
1	Bob	1997-03-27	23	Accra	550117431	1
2	Lisa	1998-03-07	22	Accra	550117431	0

Figure 10 Patient table

Vitals Table

VID	PID	Pulse	Temperature	BP	Date_
1	1	34	24	120	2020-04-18 09:00:32
2	1	34	21	100	2020-04-18 09:04:40
3	1	27	19	150	2020-04-18 10:49:10

Figure 11 vitals table

4.6 User Interface

The user interface is designed and developed using ionic framework. Ionic framework is used to render the interface to be accessible as a mobile platform both on IOS and android and a web platform. The interface is quite simple and includes the following pages to serve as the prototype:

- Login/Signup
- Dashboard
- HealthCare

Login/Signup handles unique user sessions and access to personal services. The authentication process is managed using an API that links with firebase authentication database. Hence the authentication is done using firebase; an online free database server.

The Dashboard Shows a Summary of User activities and displays recent content and health details of the user.

The health care page displays live vital recordings when the user interacts with the physical device. Hence the three vital readings are displayed on the healthcare page before sending to the medical Centre.

Chapter 5: Testing and Results

5.1 Component Tests

<u>Physical Device</u>

Pulse Sensor Test

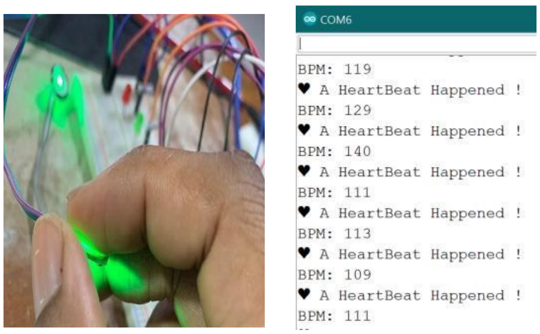


Figure 12 Pulse test and output

The pulse sensor operates as expected and record the beats per minute of an individual within the specified threshold. The specified limit, in this case, 550, is set to indicate what the pulse sensor should interpret as a heartbeat to avoid recording unnecessary data. A thing to note about the limit is that, increasing the threshold of the pulse sensor results in the likelihood of an increase in the presence of noise in the recorded data. This then distorts the input data, and hence the limit is kept within the range of 550 – 600.

<u>Temperature Sensor Test</u>

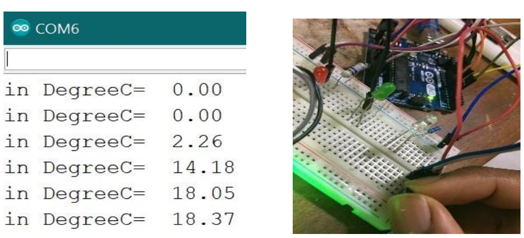


Figure 13 Temperature sensor test and output

The temperature sensor requires a little time to record its input; thus this delay accounts for the zero data depicted in the test data when the sensor gets in contact with the patient. After a delay, usually within two (2) seconds, the sensor picks up data and displays its output.

Database

During testing of the database, insertion into the table keeping record of the patient vitals revealed that the data types of temperature from the sensor and the database table were different. That of the sensor was afloat while the database expected a datatype of type "int". This has been rectified for both to have datatypes of "float." This is shown in the table below.

#	VID	PID	Pulse	Temperature	BP	Date_
5	5	2	140	18	150	2020-04-20 06:05:45
6	6	2	140	18	150	2020-04-20 06:07:17
7	7	2	140	18.37	150	2020-04-20 06:07:35

Figure 14 test table 1

Vital values with the initial temperature data type of type "int" are depicted in the table with VIDs (Vital ID's) 5 and 6. VID 7, shows the modification to the table that allows it to store temperature of data type "float."

Machine Learning

Vitals data of a patient are read into a '.csv' from which the algorithm reads the file to predict the presence of heart disease in accordance with the patient's data.

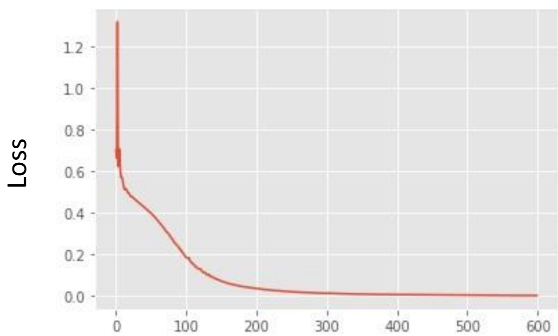
	Standard	Standard	Standard	Standard	Standard
1	Age	Sex	trestbps	restecg	thalch
2	52	1	125	1	168
3	58	1	140	0	165
4	45	1	104	0	148
5	55	0	180	2	117
6	23	1	150	1	160
7	23	1	150	0	140
8	22	0	104	1	140

Figure 15 CSV file

The .csv file contains data from the patient essential to predicting the presence of heart disease. Vitals information present: blood pressure (trestbps) and heartrate (thalch). Other required information involves Sex (Gender), and Age of the individual.

<u>Predicted Results</u>

Graph Showing losses per Epoch



N0. Of Epochs

Figure 16.i loss graph

Figure 16.i is the learning phase of the algorithm. The graph shows the losses per epoch in predicting the occurrence of heart disease in a patient from the parameters in the data set. Epoch refers to the number of time the training data is passed through the neural network. On each pass, the loss is calculated. The loss value shows how far the predicted data is from the actual data.

The combination of measured quantities that signify the presence of heart disease in the data set is the blood pressure, heart rate and temperature. Age and Sex (gender) of the individual play a minute roll in the prediction process but still have a significant influence on the outcome.

Prediction Accuracy score: **0.968**

The prediction accuracy indicates that the neural network prediction accuracy is 96.8%. This implies that 96.8% of the time, the prediction by the neuron is correct. This suggests that the error made by the algorithm lies at 0.02%. This is very low yet significant when dealing with the health of a person. To help deal with this error, the verification by the medical doctor is needed on each prediction made by the algorithm to ensure accurate results since machine error is inevitable.

<u>Test Data</u>

	Standard	Standard	Standard	Standard	Standard
1	Age	Sex	trestbps	restecg	thalch
2	52	1	125	1	168
3	58	1	140	0	165
4	45	1	104	0	148
5	55	0	180	2	117
6	23	1	150	1	160
7	23	1	150	0	140
8	22	0	104	1	140

Figure 16 test data set

<u>Test prediction results</u>

```
Predicted:    0    1    1    0    1    0    1
```

Figure 17 results

Key for Predicted Results:

No presence of Heart Disease: 0

Presence of Heart Disease: 1

From *Figure 17*, we observe that results from 3, 4, 6 and 8 show the presence of heart disease according to the data provided. Whereas results 1, 5 and 7 show no presence of heart disease.

5.2 Implementation Summary

User Interface

Interface	**Test status**	**observation**
Login/Signup	Success	An authentication process takes a little long to server processing request.
Dashboard	Not Fully Functional.	Html content is quite disorganized, showing little detail to patient's activities such as last check date and next scheduled check date.
HealthCare	Not fully functional.	Displays results of temperature and pulse/heart rate. Send button post data to database accordingly.

System test

Component	**Status**	**Observation**
Physical	Partial success	The physical component successfully reads the required body vitals of the patient and sends to the database server, excluding data concerning blood pressure.
Database	success	All data submitted to the database is successfully stored and can be fetched for analysis.
Machine learning	success	A neural network is successful at predicting the presence of heart disease.

User Interface	incomplete	The error occurs in submitting vital results from the user interface using the submit button but operates successfully when sent manually using the URL.

User Test

Component	**Status**	**Observation**
Physical	Fair	The physical device is not modelled to be user friendly due to the nature of its design; hence user interaction is quite cumbersome. The user quickly locates the pulse sensors but the temperature sensor, on the other hand, is quite challenging to identify.
Database	Fair	Due to the failure of the submit button in the user interface, result forwarding to the database must be done manually through the URL in the Arduino IDE which the user finds quite cumbersome.
Machine learning	Good	The user appreciated the result of the algorithm, but speculations arise since the device is not an official means of verification of the disease. The user is not sure if the algorithm may be given the right or wrong information.

5.3 Test Analysis

Component	Failed units	Observation/Analysis
Physical	Blood pressure calculation	The calculation of blood pressure failed due to inability to obtain results about the cardiac output. Hence current blood pressure results in the database are estimated results.
Database	-	-
Machine learning	Heart Disease Grouping	As per the requirements, the algorithm is to be available to predict the exact type of heart disease associated with the patient. This could not be done due to limitations to datasets available and instruments used to gather other vital information from the patient in order to meet this requirement.
User Interface	Submit button	The error arises in submitting recorded vitals from the ionic application directly to the database.

<u>Other components not included in the design</u>

The following are components of the currently designed system which were not added to meet the requirements:

1. <u>Virtual Doctor Interaction</u>

As part of the requirements, the system required a virtual interaction with the doctor in a case were the Machine learning algorithm may face difficulty in analysing the results. This chat feature is not included in this current project but will be subject to add in the future work.

2. Emergency Response

   The system required there to be an emergency response component whereby in a case of emergencies detected by way of the vital analysis, the nearest medical facility possible will be contacted to retrieve the patient for immediate medical attention.

Chapter 6: Conclusion and Recommendations

This project provides evidence on the fact that individuals health ca be remotely monitored and using an IOT device with an embedded machine learning algorithm acting as a secondary doctor that comes to the first aid of the patient. Further recommendations about this work lie in facilitating communication between the patient and the actual doctor and involving ways to enable doctors to have a hand in verifying the correctness of a prediction and or diagnostics made by the algorithm.

6.1 Degree to Which Project Meets Functional Requirements

The following provides a summary to which the project meets the functional requirements

Requirement	**Status**
Remote health tracking	Success using communication via wireless medium with physical device and remote server.
Disease prediction	The algorithm successfully predicts the presence of heart disease but fails to categorize it.
Access of patient medical report to health Centre	Medical facilities have access to patient's medical report via the remote server once the patient is registered to or assigned to a doctor within the medical facility.
Emergency Response to patients who require immediate attention	Unit unsuccessfully.
Full System Functionality	The systems function successfully as a unit except the ionic interface for which the user will interact with the system.

6.2 Limitations of the work or possible flaws in its design

1. Disease classification: The system is currently unable to classify the heart disease according to the type or name of the disease. This is due to the limitations of datasets provided by external sources.
2. Blood pressure calculation Unable to gain access to equipment to efficient measure blood pressure hence the estimation of blood pressure in the project.

6.3 Directions for future development

1. Virtual Chat

   A feature within the application/framework (ionic) that allows the patient to interact with the doctor over a social platform.
2. Expanding the Physical Device.

   Addition of extra instruments to measure other vital information from a patient to improve on the accuracy of prediction and detection of the algorithm.
3. Diagnostic verification

   A means provided to aid a medical facility to verify the diagnostics and inferences made by the machine learning algorithm.
4. Appointment booking

   A feature that allows the user to book appointments with a doctor via the app.
5. Heart disease grouping Improve the Algorithm to be able to classify heart diseases detected aside, just detecting their presence.

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