Detection of Levels of Blood Sugar Using Simple IoT Based Breath Analysis

Dr. Khalid Nazim Abdul Sattar[1], Dr. Mohammad Mahmood Otoom[2], Dr. Mutasim Al Sadig[3] , Dr. Nandini . N.[4]

Assistant Professor, Department of CSI, College of Science, Majmaah University, Majmaah 11952,
Saudi Arabia 1 ,2, 3,
Associate Professor, Department of Computer Science and Engineering, Dr. Ambedkar Institute of Technology, Bangalore – 560 056 4
ORCID: 0000-0002-0759-0512 1, 0000-0002-5818-9868 2, 0000-0002-5614-4527 3, 0000-0002-3230-0628 4

Summary
In recent years, the world has witnessed rampant growth in science and technology. Internet has been through a lot of revolutions to assume its present form. Being a key player in the field of network and connectivity, it has become a part and parcel of the human society. It is now the time to connect with the objects that humans depend on the most, to broaden the functionality it has to offer by what is popularly known as Internet of Things (IoT). Healthcare, being one of its major areas of application is turning out to be a boon for people[6,7]. The statistical analysis on diabetes based on the current Indian population is expected to double by 2025. The objective of this paper is to design a device based on IoT which provides a consistent technique to measure blood sugar level. It has been established that the level of ketone in the breath is directly linked to the sugar level of a person. For this purpose, the device collects the sample of the breath when the patient blows into the mouthpiece and senses the level of ketone in addition to the temperature and humidity levels of the breath that minimizes the need for any human interference.

Key words:
Breath Analysis, Internet of Things (IoT), Acetone, Ketone, Diabetes mellitus ,Diabetic ketoacidosis (DKA), Smart Devices.

1. Introduction

The primary objective of this system is to design a Diabetic health care monitoring system that overcomes the shortcomings of invasive methods of testing blood sugar level[6].
One such application in healthcare is to monitor the patient health status through IoT[4].
The ideology proposes a method that minimizes the need for any human interference and provides a device capable of reading the diabetic level through acetone gas present in the breath of patient and is recognized as an easier technique and will aid in fast diagnosis of diabetes[2,10].
Based on the present statistical analysis the major threat to mankind is diabetes and it is found that there are about 72 million ailing with diabetes, and its prevalence is said to be double by 2025 in India.
When the fat in the body starts breaking very fast, the liver converts the broken fat into ketones that makes the blood acidic in nature resulting in a life-threatening situation termed as Diabetic ketoacidosis (DKA)[6].
As per medical diagnosis, when the body fails to produce insulin, a resulting condition is termed as Type-1 diabetes[1], which is usually diagnosed at any age group and it is especially found more common with the children and adults, this makes the diagnosed patient to take insulin every day to live healthy.
The sweet odour of ketobetic and diabetic individuals is found in acetone, a normal breath component and is termed as the biomarker for diabetes[12].
In contrast, in the diagnosis of Diabetic Keto Acidosis(DKA) blood and urinary ketone detections are found to be invasive, painful, and inconvenient methods.
The intent of the system is to design a device based on IoT which provides a non-invasive technique to measure blood sugar level. It has been established that the level of ketone in the breath is directly linked to the sugar level of a person. For this purpose, the device collects the sample of the breath when the patient blows into the mouthpiece and senses the level of ketone in addition to the temperature and humidity levels of the breath[5,6].
Overall system adopts the concept of IoT to build the proposed device to simplify the diagnosis and personal monitoring of the patients related to diabetes[7].

Objectives of the proposed work:

1. In this designed system, an Arduino UNO has been used to analyze and compute the patient health.
2. Use of smart devices to collect sugar level, temperature and humidity that will aid in evaluation of the health condition of the patient.
3. The diagnosed results are displayed on the android device used.
4. The results generated are stored onto the database for future references and are accessible from any location in case of emergency without minimal delay.

Structure of Paper:

The rest of the paper comprises of six sections, Section 2 proceeds with literature survey and findings. The methodology is as presented in Section 3, In Section 4 the implementation details of each part of the system is discussed, result outcomes are as shown in section 5. Finally, the conclusion and future work are followed in sections 6 and 7.

2. Literature Survey

a. Internet of Things(IoT):

In recent years, the world has witnessed rampant growth in science and technology. Internet has been through a lot of revolutions to assume its present form. Being a key player in the field of network and connectivity, it has become a part and parcel of our lives. It is now the time to connect with the objects that we depend on the most, to broaden the functionality it has to offer by what is popularly known as Internet of Things (IoT). Healthcare, being one of its major areas of application is turning out to be a boon for people[5,7].

This has further given rise to the use of smart technology by developing mobile applications and sharing the data on websites in heterogeneous environments. One such application in healthcare is to monitor the patient's health status through IoT, a simple illustration is as shown in fig 1.

Fig. 1 Internet of Things in Health Care

b. Motivation:

To design a Diabetic health care monitoring system that overcomes the shortcomings of invasive methods of testing blood sugar level. The ideology proposes a method that minimizes the need for any human interference and provides a device capable of reading the diabetic level through acetone gas present in the breath of patient which is connected to the internet that could help the patient and the doctor for further course of action.

c. Research Findings:

In this present era Diabetes has become a prime concern across the globe, this is due to the changing lifestyles in which usually the blood sugar level gets too high that affects the body's ability to either produce or use insulin. An early diagnosis refers to start the treatment and take steps toward a healthier lifestyle.

In this section the main objective is to understand the various terminologies related to the domain of interest and has done by visiting related online websites and various journal papers as discussed below.

In [1] authors have designed a system for the diagnosis of diabetes mellitus that provides the scope for future directions for the diagnosis of non – invasive diabetes to make it a clinical practice.

The authors have discussed the development and importance on non-invasive glucose monitoring system towards regular monitoring to overcome the serious short- and long-term implications of diabetes[2]. Further to a note, the non- invasive method demands tremendous improvements to replace the existing conventional glucose monitoring devices to aid painless support to the patients to control their blood glucose levels[11].

In the review paper by Maryamsadat Shokrekhodaei et.al, the authors have presented a multidisciplinary view related to blood glucose and other tissue components based on physiological and biochemistry theory on non-invasive glucose measurements for the benefit of community such that the effect can be minimized further.

Authors in [4] have demonstrated the importance of remote access and monitoring the real time data of the patients by doctors through an android based user friendly interface , In their research they have used the IoT system to assist the patients with self-monitoring interface that help the doctors to provide any further treatment required based on the ketone readings.

Vasantha kumar. R et.al, proposed a new multidimensional approach for diabetes care that encompasses the system to monitor the glucose level, blood pressure and temperature of the patient under diagnosis with the historical data as available on cloud to facilitate the doctors to provide a better treatment.

The use of a handheld health care on monitoring diabetic level by using the breath of the patient has been proposed by Ruhani Ab. Rahman et.al.

IoT based wearable health care system has been implemented to monitor and support active and assisted living [7], the researchers have also concluded the effectiveness towards developing a mobile application to aid treatments on hand held devices by sharing secure access to the data.

The clinical parameters for type 2 diabetes by using the breath acetone has been discussed in [8].

In [14], the author has discussed the therapeutic effects of ketone body on metabolism, the paper also focusses the impact of metabolic inefficiency which is due to the elevations of free fatty acids and this problem has been

addressed through new diets that comprise of ketone bodies[9].
The concentration of acetone in the exhaled breath and its effects has been estimated by using a trained and tested data comprising of non-diabetic and pre-diabetic patients. By using Artificial Neural Network, the features are extracted from the output waveform of the sensors[10].

d. Existing System:

There are different ways of Conducting the diabetic testing and listed below are a few frequently used common methods[9,11]:

1. Glycated Hemoglobin (A1C) Test.
2. Random Blood sugar (RBS) Test.
3. Fasting Blood sugar (FBS) Test.
4. Glucose Tolerance Test also termed Oral Glucose Tolerance Test.
5. Urine Analysis.
6. Gestational Diabetes Mellitus (GDM) / Gestational Diabetes Tests.

From the related works and research findings, the shortcomings of invasive methods have proven to be costly and time consuming in some cases[1,3,11]. Patients diagnosed for diabetes must be monitored continuously and cannot afford to visit doctors or diagnostics centers daily, although the present day has the facility for home pickup of blood samples, it has incurred an additional overhead to get the results on time. Based on research findings it has been found that the test performed through taking blood samples are only 75% accurate and the Urine test is past hope.
Further, IoT has left the end users with several challenges to be addressed when it comes to security and inter connectivity issues as a prime concern.

3. Methodology

The intention of the proposed system is to design a device based on IoT which provides a non-invasive technique to measure blood sugar level. It has been established that the level of ketone in the breath is directly linked to the sugar level of a person. For this purpose, the device collects the sample of the breath when the patient blows into the mouthpiece and senses the level of ketone in addition to the temperature and humidity levels of the breath[9,10]. The design of system as shown in fig 2, involves displaying the reading on the built-in LCD screen and in the Android mobile application which also provides for graphical representation of sensitivity characteristics of each of the fields mentioned.

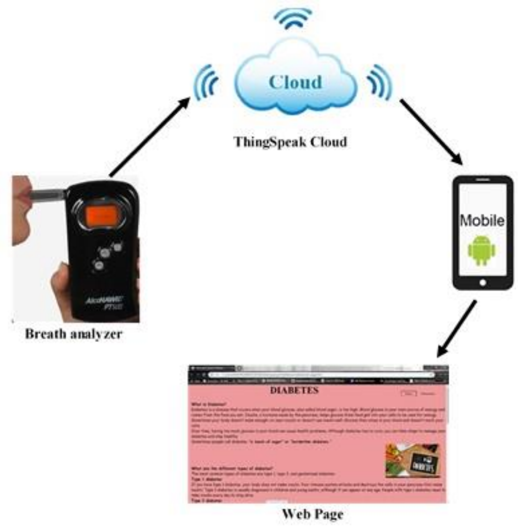


Fig. 2 System Design.

a. Breath analyzer: A component which consists of the Figaro TGS sensor used to collect the breath sample for analysis.
b. ThingSpeak: A service that supports IoT applications and allow the users to analyze and visualize uploaded data using Matlab® .
c. Android Application: An app that enables the patients/ doctors who have smartphones to view readings of the sensor and maintain a record of the same.
d. Web page: This displays the readings of the sensor to the patients and doctors who do not have access to smartphones or for those who do not wish to install the application.

4. Implementation

Some of the methods or algorithms used for the design of the system are: Breath Sensor, Arduino UNO, and LCD display[15-18], the proposed design requires the following hardware and software components.
A. Hardware Requirements:

1. Arduino UNO
2. Esp8266
3. Tgs 822
4. DHT 11
5. Buttons
6. Mouthpiece Case
7. LCD
8. Potentiometer
9. Breadboard
10. Jumper wires

B. Software requirements:

1. Arduino IDE

2. Thingspeak

The designed system comprises of different modules as shown in fig 3 ,the various hardware components as listed above are used in the setup of the system and connected to the Arduino UNO microcontroller[15,18].

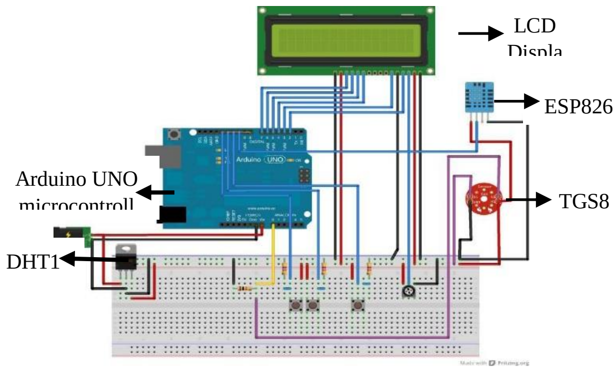


Fig. 3 Circuit Diagram.

Thingspeak cloud as shown in fig 4, allows the use of MATLAB to analyze and visualize the data[16]. Patients can interact with doctors via mobile application .

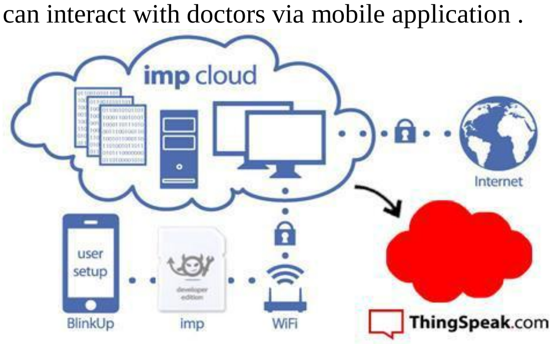


Fig. 4 ThingSpeak Cloud.

The main component here is ketone, but it cannot be detected directly, hence acetone is used as key element to detect ketone level. The User is provided with a mouthpiece, as it is a non- invasive method to measure the ketone level[10]. A fruity odour smell would be present in user breath. This fruity odour smell is acetone, used for measuring glucose level in breath[9].

The Figaro TGS sensor built into the device plays the major role of detecting the ketone level in the breath. The accuracy of the sensor depends on how long it has been switched on for. Typically, it requires about ten minutes for the sensor to achieve its peak working condition after which the patient can blow into the device to obtain results. The results are displayed both on the LCD screen of the device, which can be refreshed for consecutive readings and in the mobile application. The latter can be used for recording and monitoring purposes[17].

A. Arduino UNO:

Fig 5 shows the Arduino UNO, a microcontroller which is an essential component as used in the system. This board serves as an interface to different devices that can be connected through 6 analog and 14 digital I/O pins and is programmed in Arduino IDE. Further, ThingSpeak allows the platform for real time updates for the patient through the mobile app or via the web interface[15,16].

Fig. 5 Arduino Uno.

B. ESP8266 Sensor:

This is a Wi-Fi enabled sensor as shown in fig 6, most known for supporting IoT applications[19] and is used to transmit data from Arduino to ThingSpeak[16].

Fig. 6 ESP8266 Sensor.

C. TGS822 – Electro Chemical Gas Sensor:

The amount of acetone in a person's breath is detected using the gas sensor FIGARO TGS 822 as shown in fig 7. Furthermore, the factors namely gas concentration, humidity and temperature determine the concentration of the acetone[17].

Fig. 7 Figaro TGS 822.

Using equation 1, 2 the Diabetic value graph is determined and is seen increasing, when tested for different users and the corresponding results have been illustrated in fig 8.

The Sensor Resistance (Rs) is calculated by using the following formula:

$$R_S = \left(\frac{v_c}{v_{RL}} - 1\right) \times R_L \qquad (1)$$

The Power dissipation across sensor electrodes (Ps) is calculated by the following formula:

$$P_S = \frac{v_c^2 \times R_S}{(R_S + R_L)^2} \qquad (2)$$

where V_c= Circuit Voltage, V_{RL}= Load Resistor, R_L=Load Resistance, R_s= Sensor Resistance.

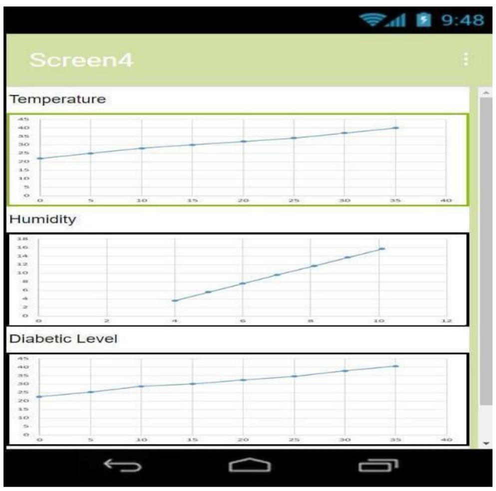


Fig. 8 Temperature, Humidity, Diabetic level of the patient

The temperature and humidity graph are almost in a straight line as from a user's breath universally, it varies from 27-28 and 28-30% humidity, respectively. The Diabetic value graph is seen as an increasing, as tested for different users.

D. DHT11 – digital temperature and humidity sensor:

This sensor helps to determine the gas concentration of the patient as shown in fig 9, when the patient blows into the sensor a couple of ties it is observed that the temperature value between(28-290C) and humidity of the breath was stable at around 60%.

Fig. 9 DHT 11 Sensor.

E. Mouthpiece Case:

The patient is required to blow through this instrument as shown in fig 10(a), that collects the breath from the user to the breath-check device from this it would go to the section in the device which is connected to the DHT11 and Figaro sensor. The dimension of mouthpiece is 3×075cm, and extension of mouthpiece is 2cm in length.

Fig. 10(a) Breath check device.

To get exact readings, a suitable mouthpiece as shown in fig 10(b) is chosen and utmost care is taken to ventilate all the gases.

Fig 10(b) Mouthpiece

F. LCD Display:

The humidity, temperature, resistance, minimum, maximum values of acetone are displayed as shown in fig 11.

Fig. 11 LCD Display.

G. Android Application:

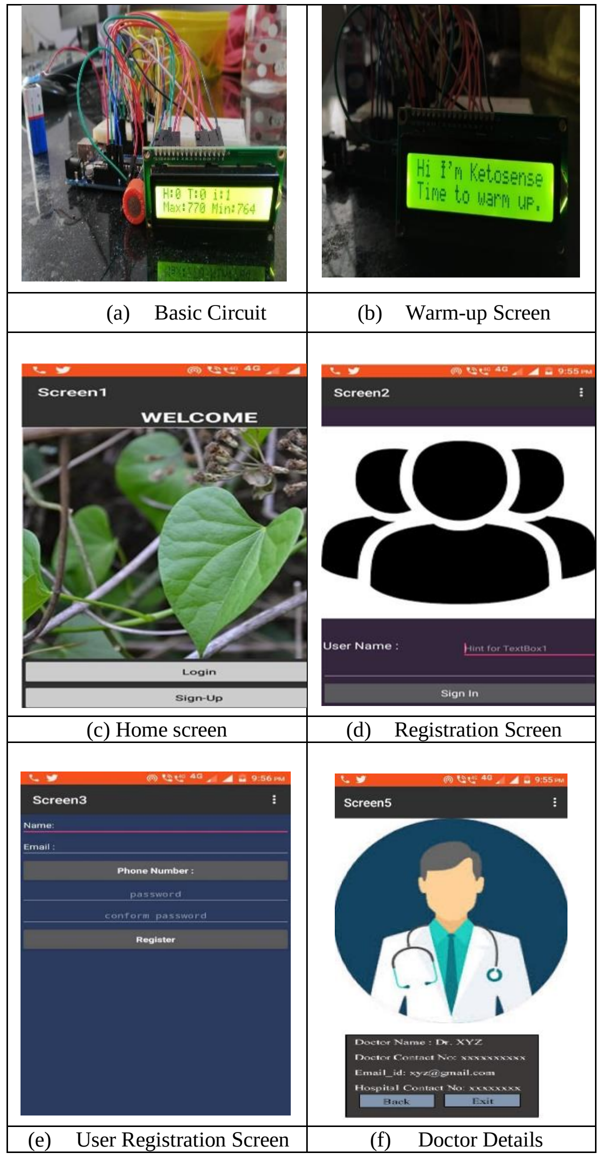
The android application consists of display sections to provide information about the reading of the ketone level, temperature, and humidity. The readings are displayed in their respective screens in pictorial format, the user login screen is as shown in fig 12. The data is stored on TinyDB (lightweight document oriented optimized database).

Fig. 12 User Login Screen.

5. Experimental Results

This section gives the circuit setup and user interfaces as used in the development of the system as shown in fig 13(a) to 13(f) below.

Here, the results that are obtained after execution of the various algorithms and software are subject to analysis. This is further used in drawing conclusions related to the various parameters of the system like accuracy, complexity, usability, etc. The results which are obtained help the user in understanding the true purpose of the system and the need for its implementation.



(a) Basic Circuit (b) Warm-up Screen
(c) Home screen (d) Registration Screen
(e) User Registration Screen (f) Doctor Details

Fig. 13(a) 13(f) Hardware setup and User Interfaces.

Fig. 14 Information Web Page.

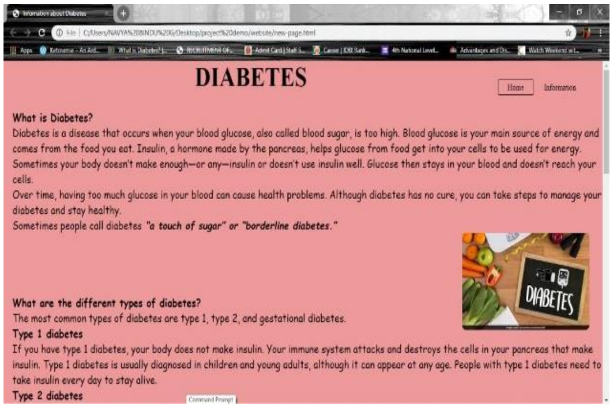


Fig. 15 Patient Web Page.

Web page interfaces as shown in Fig 14 and Fig 15, provide necessary details to the users regarding information on Diabetes and its implications.

a. Performance Evaluation

On careful analysis of the obtained results, a conclusion can be drawn on the accuracy of the Figaro sensor. The probability of the presence of the breath acetone depends on many factors[12,13]. The factors to be considered here is whether the user is tested before having breakfast or after having breakfast or pre-lunch or post lunch or at some random time.

While developing the test cases all possible combinations were taken into consideration and the results are summarized in table 1 below.

Table 1: Patient Pre & Post Diabetic analysis

Test Case Id	Test Category (Pre / Post / Random)	Expected output	Obtained output	Result
1	Check for Non-Diabetic Patient Pre-lunch	100-125 Mg/dl	110 Mg/dl	Pass
2	Check for Non-Diabetic Patient Post-lunch	100-125 Mg/dl	125 Mg/dl	Pass
3	Check for Non-Diabetic Patient Pre-lunch	> 125 Mg/dl	200 Mg/dl	Pass
4	Check for Non-Diabetic Patient Post-lunch	> 125 Mg/dl	250 Mg/dl	Pass
5	Check for Non-Diabetic Patient Pre-lunch	100-125 Mg/dl	100 Mg/dl	Pass
6	Check for Non-Diabetic Patient Post-lunch	100-125 Mg/dl	120 Mg/dl	Pass
7	Check for Diabetic Patient @ Random	> 125 Mg/dl	150 Mg/dl	Pass
8	Check for Non-Diabetic Patient Post-lunch	100-125 Mg/dl	105 Mg/dl	Pass

6. Conclusion

The goal of the proposed system was to design a device based on IoT that provides a non-invasive technique to measure blood sugar level. It has been established that the level of ketone in the breath is directly linked to the sugar level of a person.

The system designed involves displaying the reading on the built-in LCD screen and on the Android mobile application which also provides graphical representation of sensitivity characteristics of each of the fields taken under consideration.

Further, a web-based user interface was designed to help the patients to avail the best use of technology.

7. Future Work

There is no perfect technology, each technology has specific features that work well in certain situations As a part of future work, artificial intelligence and machine learning can be embedded to the system to help in classification and prediction of data to get more accurate results. Additionally, RFID tag could be used for unique identification of the breath-check.

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Dr. Khalid Nazim Abdul Sattar, Assistant Professor, Department of CSI, College of Science, Majmaah University, Az Zulfi, Kingdom of Saudi Arabia, received his B. E. (CSE) Degree from Bangalore University, M. Tech(CSE) from VTU Belagavi, and Ph.D. in Computer Science & Engineering from Singhania University, Rajasthan, India. He has 20 years of research and teaching experience and his research expertise include but are not limited to Image processing, digital signal processing, Artificial Intelligence, Internet of Things, Cryptography, Data & Network Security and Data mining.

Dr. Mohammad Mahmood Otoom, Assistant Professor, Department of CSI, College of Science, Majmaah University, Az Zulfi, Kingdom of Saudi Arabia, received his B. Sc. Degree(Computer Engineering) from Yarmouk University, Jordan, M.Sc. Degree(Computer Engineering) from The National University of Malaysia (UKM), and PhD Degree (Computer Engineering) from University Of Rome ,Italy. He has 10 + years of research and teaching experience and his research expertise include but are not limited to Artificial Intelligence, Parallel Computing, Internet of Things, Machine Learning, and Biomedical Engineering.

Dr. Mutasim Mohamed Al Sadig, Assistant Professor, Department of CSI, College of Science, Majmaah University, Az Zulfi, Kingdom of Saudi Arabia, received his Bs in Science and Technology & M. Ec(CS) from GAZERA University, Sudan. PhD in Information Technology, from Academic Sudan University. He has 20 + years of research and teaching experience and his research expertise include but are not limited to and Data Mining, Biometric Identification System , Software Engineering, Artificial Intelligence, and Computer Networks.

Dr. Nandini. N., Associate Professor, Department of CSE, Dr. Ambedkar Institute of Technology, Bengaluru, Karnataka State, India, received her B. E. (CSE) & M. Tech(CNE) from VTU Belagavi, Karnataka and Ph.D. in Computer Science & Engineering from Bharathiyar University, Coimbatore, Tamil Nadu, India. She has 17 years of teaching experience and his research expertise include but are not limited to Data mining ,Image processing, Internet of Things, and Computer Networks.