Food Quality Monitoring Based on IoT Techniques

Rashmi Tailor, Smit Parikh, Kamalakannan Kumar,
and Dr. Hosam El-Ocla, *Member, IEEE*

Abstract—As of late, there are slowly expanding requests of quick, profoundly delicate, and specific techniques in food safety. In our bustling life, most people are eating out and ordering food using online food delivery applications. As on the buyer side, food quality and cleanliness could assume a significant job. For instance, fruits and food products cultivated in South America are generally shipped via freight transports more than 21 days to Europe. During this extended excursion, the outcomes could, as of now, begin to turn mouldy. In circumstances where a shipment of products has just become awful so the clients will end up consuming unhealthy food. Also, recently by consuming unhealthy food from the Wuhan food market leads to Coronavirus disease (COVID-19) and widely spread all over the world. This paper came up with a model to monitor the food quality right away before consuming it. Therefore we have been developed a system called ”Edispotter.”, an IOT based food quality monitoring system. With the power of Raspberry Pi and ESP 32, which will help to fetch the essential parameters from the food product via different sensors. Then the data are being processed in the Redis database in an Amazon Web Services cloud environment through which consumer receives the status of the food in an Android Application.

Index Terms—Raspberry Pi, ESP32, Sensors, Food Quality Monitoring, Android, MQTT(Message Queuing Telemetry Transport), HTTP Environmental Factors, IoT, Predefined value, AWS(Amazon Web Services) Storage.

1 Introduction

Nowadays, food safety and hygiene is a significant concern to prevent food wastage. The calculated difficulties associated with the food supply are anyway gigantic [1]. A considerable number of food items are dispatched worldwide via freight because of cost factors. Massive ships travel moderately slow on long routes, which might take the transportation of products as long as 30 days, which can prompt uncontrolled ripening or development of mould, particularly in food items like fruits. The capacity to distinguish food deterioration early offers a few advantages, like the optical sensor system to detect mould [2]. Due to these mobility issues, food products get decompose before it reaches consumers, which motivated us to create an approach to control the ripening of fruits.

Also, other identification strategies for airborne spores, for example, the one portrayed by Blank et al., are likewise not appropriate because of the way that forms that colonize bananas [3]. The ripening and spoilage forms in bananas are emphatically coupled to each other, as the ripening procedure diminishes the resistance of bananas against mould contamination. Bananas require and produce ethylene gas during the ageing procedure, which prompts a chain reaction [4]. Modern cargo containers carrying bananas, in general, come in variants equipped with an array of sensors as well as sensor-free options. Typical sensor arrays include sensors for measuring temperature, CO2 and O2. So the primary solution for real-time monitoring and controlling cargo containers is carrying foods

- *Rashmi Tailor, Smit Parikh, Kamalakannan Kumar and Dr. Hosam El-ocla are with the Department of Computer Science, Lakehead University, Thunder Bay, Ontario, Canada.*
E-mail: (sparikh3,rtailor,kkumar1,hosam.elocla)@lakeheadu.ca

such as bananas [5]. So at the ends, it prompts us to use an easy level approach, which has a good response time to detect the temperature and gases like co2 and 02 can be measured and monitored.

Several other studies showed that environmental factors have a significant effect on the meat and its related products. They are highly subjected to spoilage due to the bacterial impacts such as ammonia(NH3) during their production, distribution and storage [6]. By utilizing an NH3 sensor of low detection breaking point and high sensitivity, meat would be perceived at the start of the spoiling procedure before that dependent on visual appearance. So in one of the systems, adaptable NH3 sensors were created utilizing polymer poly(3,4-ethylene dioxythiophene): poly(styrenesulfonate) PEDOT: PSS/silver nanowire (AgNW) composite film as the dynamic layer. With AgNWs of enhanced fixation consolidated into the PEDOT: PSS film, the sensitivity was altogether improved [7]. So, in this case, it drives us to create a system that can detect the level of ammonia gas emitted by meats.

In the dairy sector, some farms are enhanced versions of conventional farms as they use real-time information to provide farmers with value-added advantages. It has driven farmers to increase significant insights on time, urging them to efficiently exploit their accessible resources and improve both the amount and quality of milk produced [8]. It proposes a proactive approach that monitors the measurements of the temperature and the level of microorganisms in milk. The data is then used to decide the status at which the storage tank should hold the milk as per models. The status is then compared with the tank's real status, and if they are unique from one another, it will prompt the farmers to take the necessary preventive actions to manage the quality of milk. The developed proactive management of the raw milk quality approach is modelled by using a rule-based system and machine learning techniques with a significant level of accuracy [9]. This influences us to design a proposal to detect the temperature as well as the level of microorganisms generating during milk production flow.

Recently, a pandemic disease has occurred all over the world, which is known as COVID-19 emerged in 2019, reported in Wuhan, China. This disease is generally found in mammals and animals, such as bats. The root cause behind this is due to consuming contaminated food, i.e. bat from the food streets of Wuhan as per the WHO(World Health Organization) reports [10].

So to overcome the above constraints occurring in food items, this paper shows a food quality monitoring device based on IoT(Internet of Things) techniques. It is designed likewise that will collect real-time information on various environmental factors. Such as temperature, humidity, air quality, and pH(Potential of Hydrogen) level using IoT enabled sensors using two chip-set boards, i.e. Raspberry Pi and microcontroller ESP32. This set of information is then transferred to a mobile application device using WIFI/Ethernet through a light weighted protocol, also known as MQTT (Message Queuing Telemetry Transport).

2 Related Work

Even though examination of food quality checking framework utilizing ESP32 and raspberry pi has been expanding consistently, as of late, there are practically no investigations that have coordinated ESP32 with raspberry pi, and taken various factors which influence to food quality. Right now, we will survey the related works of checking multiple kinds of food utilizing different innovations to guarantee the quality of the food.

Smart city administrations deal with the city's advantage by incorporating Information and Communication Technology (ICT) and the internet of things (IoT) [11]. In [12], they have introduced a model to deal with raw milk for waste identification. Different contemplates shows raw milk contains the microorganisms, so there is a need for a continuous framework which will screen the quality of milk. The structure works with a set of various sensors [13], which are associated with the Arduino board through TCP/IP. Thus all information is displayed in an android application through which the client can see the quality of milk he/she gets. However, Nonetheless, this framework is attainable for just milk or liquid food products. They are concentrating on gas, which isn't the only factor for the deterioration of milk or any food. For this, they have utilized the cloud, which doesn't make this framework profitable. Also, the hardware they are using is Arduino, which has limited libraries. So to make a better prototype, Raspberry pi is recommended.

Milk is a profoundly short-lived item [14]. A more significant part of work, [15]-[18] measures milk quality as per its bacterial list. In this paper, a proactive approach is used, which monitors the temperature and the level of microorganisms in milk. Then it is used to decide the status at which the capacity tank should hold the milk as per standards by using a rule-based approach and machine learning techniques. Then this status is compared with the tank's real condition, and if they are not the same, it will prompt the farmers to take the necessary preventive actions. Nevertheless, this system is not as portable as the infrastructure design is for industrial use. Also, it is not cost-effective because the system uses excessive hardware while the functionalities are limited. Furthermore, the technology focuses on just one factor, which is a bacterial count. Where in milk, its pH(potential of hydrogen) level, humidity and air quality also plays an important role. So it's considerable to use multiple sensors to get an accurate result that can sense the above-listed factors.

Meats decayed are because of bacterial impacts during production, dispersion and storage. It is critical to creating economic and advantageous approaches for reviewing or checking meat items to protect their hygienic quality, which could be useful for the market as well as end customers. Deterioration procedures of meat with microorganisms can be seen by a difference in the ammonia (NH3) content in the meat [19]. In this paper [20], NH3 sensors were created using PEDOT: PSS/silver nanowire (AgNW) composite film as the dynamic layer. At long last, the sensor was incorporated with a self-structured convenient data obtaining system to screen freshness of pork [21]. Although, PEDOT is not readily available in the market and to compose it with AgNW along with PEDOT is a difficult task that cannot be done by the non-chemist person. Overall, the process is time-consuming, and the major disadvantage is a poor solubility, which is partly circumvented in the PEDOT-PSS composite.

In a traditional quality checking system, data altering and centralized storage have become boundaries to unwavering quality. Fortunately, [22] block-chain is a promising innovation that is tamper-proof and has decentralized storage. This paper presents a smart quality checking system for fruit juice [23] production. During the real production process, smart contracts are executed to record creation data on a block-chain. In light of the assessment result, smart contracts will choose whether the creation procedure can be continued or not. However, in some aspects, block-chain technology is still immature and has not yet transformed chain activities of critical supply. Critical supply chain activities incorporate the difference in standard resources, unrefined materials, and parts into a finished thing that is passed on to the end customer. For example, storage and data processing systems of each participant must be able to process all the transactions and not only their own. That means sacrificing efficiency to gain in security, but it entails higher demands in terms of a technical infrastructure, which makes them more expensive. Moreover, optimization is needed to increase the search speed of storage structure data that are preserved on a block-chain.

Likewise, modern IoT gadgets, for example, RFIDs(Radio Frequency Identification) and sensors [24], can be added to the system for the acknowledgment of a completely programmed quality checking system.

Consistent sensor-warming voltage is usually used in the electronic nose [25]. This paper [26] targets presenting an ideal temperature modulation method of gas sensors for accomplishing minimal effort, quick, and accurate detection. It contains the temperature modulated gas sensing system with a highly efficient extreme learning machine that follows a random projection-based learning mechanism. A temperature self-balanced gas detecting system is proposed in the E-nose system for IAQ (Indoor Air Quality) observing application. Temperature modulation acknowledged by creating an occasional ramp signal to control the yield of the N - channel MOSFET (metal-oxide-semiconductor field-effect transistor), working in a linear district. However, extreme learning machines can't encode more than one layer of reflection. Also, the effectiveness and efficiency of the system are not considered, which is the major drawback of the system. As they are using an Extreme learning machine, it requires extensive storage to run the expensive operation.

The quality of drinking water plays an essential job in the well-being and health of people [27]. In [28] monitoring, it's defined as the assortment of data in certain areas and at standard intervals to give information [29]. In [30], the physicochemical parameters of water quality are represented as stream, temperature, pH(potential of hydrogen), conductivity, and oxidation-decrease potential. The sensors are designed from first standards and executed with signal conditioning circuits associated with a microcontroller-based measuring node. Zigbee [31] and transmitter modules are used for correspondence between the estimating and notification nodes. The notification node yields a sound alert when water quality parameters arrive at dangerous levels. Although, the system does not contain a turbidity sensor, yet it is a significant quality monitoring parameter. However, for correspondence, they have used ZigBee, which mainly includes short-range and low data speed. Besides, It requires high maintenance. The present structure can show the parameters continuously. Anyway, a past filled with the readings isn't accessible. Hence information logging of the sensor estimations could likewise be considered.

Cereal grains are significant food stocks that can be securely put away for an extensive period whenever stored at a suitable temperature and moisture content [32]. Since grains, such as corn portions, are moderately massive contrasted with the size of traditional microsensors. A printed circuit board(PCB) bordering field sensor was created to identify the soaked up moisture in corn pieces. In [33], PCB technology has been used to understand an assortment of scaled-down devices, including natural sensors [34], accelerometers, tunable antennas [35], and microfluidic gadgets [36]. In PCB-based sensors and tools, the standard materials and create forms for assembling standard PCBs are used to acknowledge small scale highlights for detecting functions. Nonetheless, PCB requires extra processing, which is time-consuming and expensive. It is non-solderable above 17 in and finds difficulty with other surface finishes. Besides, it can not resist high temperatures and acid-alkali.

Odour recognition by using an electronic nose(E-nose) [37] is an intriguing, however challenging issue in machine olfaction. Yin et al. [38] proposed a temperature modulation method in E-nose for gas recognition. In the paper, the proposed transferring odour recognition model is called cross-domain discriminative subspace learning (CDSL). The model is prepared on a readied source domain data set from a pro-E-nose framework. Yet tried on another target domain data set from a slave system B or C with a comparable sort of the ace framework A, With the ultimate objective that single area based odour recognition model may not be adjusted to another domain. However, the E-nose system is not feasible to check the actual quality of food as it does not contain any sensors which can sense the gas, pH(potential of hydrogen), or other environmental factors. By adding into this, multiple E-nose is more expensive. Also, the modulation method is ancient in this approach.

Industrial baking of sponge cakes requires different quality pointers to be estimated during production. In the study, a single sensor hyperspectral imaging approach, which can quantify both sponge moisture content and hardness at the same time. Hyperspectral imaging (HSI) [39] is a spectroscopic imaging method that permits spatial and spectral pictures of a scene to be gained. Unlike ordinary cameras that test red, green, what's more, blue districts of the spectrum, HSI [40] systems catch hundreds or a large number of pictures, each at an alternate wavelength of the electromagnetic spectrum. However, the developed models seem to perform better for estimating moisture in white sponges than in chocolate sponges. It illustrates a smaller range of moisture changes. They display a higher fluctuation in general sponge moisture, which prompts a more fragile relationship between ground-truth estimations and anticipated qualities for this sort of sponge. Besides, the primary disadvantage of this method is cost and complexity. Additionally, Significant data storage capacity is necessary. Since hyperspectral cubes are large, multidimensional datasets, probably passing hundreds of megabytes.

To overcome the above challenges, it motivated us to present the idea of integrating multiple sensors such as pH(potential of hydrogen) level sensor [41], temperature sensor [42], moisture level sensor [43], light sensor [44] and air quality sensor [45] with the raspberry pi [46]. The real-time information is moved from raspberry pi to an android device through the MQTT(Message Queuing Telemetry Transport) convention [47]. Here, we are using an android device for displaying real-time data [48]. By using multiple sensors and keeping all the environmental factors into consideration, the quality of food is being monitored with an accurate result.

3 EDISPOTTER

According to the Centers for Disease Control prevention [49] research, it was estimated 48 million people get sick from a foodborne illness every year [50]. The basis of predicament is the lack of inspection by the consumers before they consume. Usually, the quality of food has assessed using a food quality monitoring system whereas, food monitoring applications are designed and limited for industrial purposes alone. Still, those techniques are not applicable for the day-to-day food consumers who seem to be a significant challenge in the existing system.

So, Edispotter has addressed the challenges by leveraging the power of the IoT devices [51] to deliver the status of the food in a mobile app by considering appropriate metrics of the food. By referring to Table 2, we can see the existing system does not focus on checking the quality of food before consuming it. So we come up with an idea which delivers real-time information about the quality of data.

Recently a pandemic COVID-19 (Coronavirus Disease) case first emerged in late 2019, when it has reported in Wuhan, China. The leading cause of the disease confirmed a new kind of virus, and the contamination has spread to numerous nations around the globe and turns into a pandemic. So far, approximately 4.3 million positive cases and more than 292,000 people have died globally. While the root cause is due to consuming contaminated food from the food streets of Wuhan as per the WHO(World Health Organization) reports, this root cause motivated us to work on this project more intensively.

Our following prototype addressed the

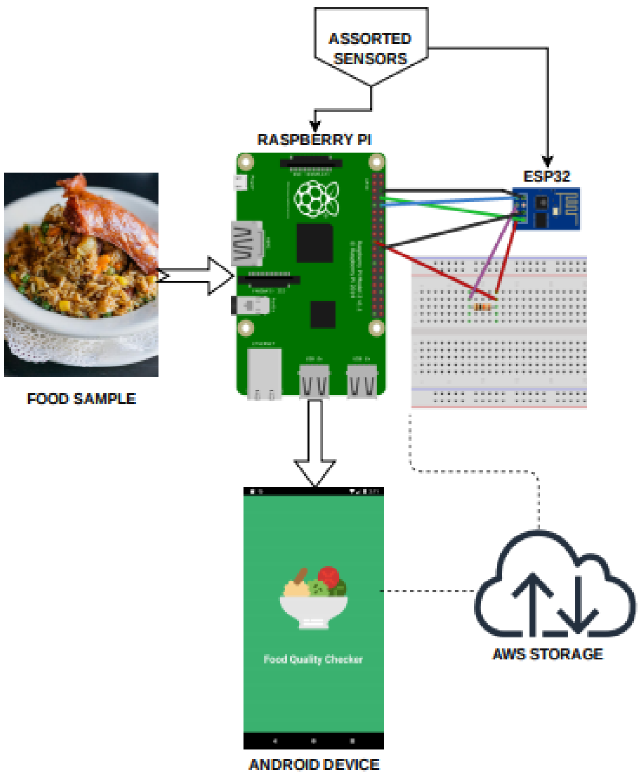


Fig.1: Architecture

problem statement and challenges into two contrasting scenarios.

- Firstly, the entire model works as per the diagram stated, i.e. Fig.1, once the user receives the food, the whole meal sensed using a food monitoring device and values are passed to the consumer personal android mobile phone to view the status of the food.
- Secondly, we enhanced our model for generating a dashboard for all the dishes at the restaurants so that customers can order the food by knowing the status of it from the dashboard.

Our implementation was powered by Raspberry-Pi [52] for I/O operations, which have integrated with different sensors to sense the following parameters, namely Temperature, Light, Air quality, pH(potential of hydrogen) level, gas. These parameters act as a sender for transferring the data via ESP8266/ESP32 to the WiFi router. The processed data from the CDR(Central Data Repository) is sent forward to the Android interface request for the analysis from the AWS (Amazon Web Services) back-end server. The Python programming code running over the device implements the various functionalities of the project, which includes reading the sensor data, converting them into strings, processing them and passing them to the IoT(Internet of Things) platform.

Although our framework is flexible, it can use different sensors which are available in the market with different circuit design and a few different specifications. The reason we used the sensors shown in Table 1 is, they give an accurate result. Also, it is cost-effective and trendy in the market.

In Table 1, the name of each sensor is mentioned. It includes each sensor's image along with the name.

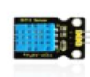
SENSOR IMAGES	SENSOR NAME
	TEMPERATURE AND HUMIDITY SENSOR
	LIGHT SENSOR
	AIR QUALITY SENSOR
	GAS SENSOR
	WATER PROOF pH SENSOR

Table 1: Sensor Names

- **Temperature:** As you can see, the very first image is of temperature and humidity sensor. For most of the food items, a specific temperature and humidity are required. There are many temperature and humidity sensors available in the market, which has a primary, ultra, low-cost digital temperature and humidity sensor. Also, it has low power consumption and excellent long-term stability.

- **Light:** The following one is a light sensor. We need a light sensor for verifying the colour of food. Mould can change the colour of the food. For this system, we need a light sensor that has the capability of measuring both broadbands (visible plus infrared) and infrared light. Colour gives relevant information to question acknowledgment; this data can be separated and utilized for different purposes. The colour sensor recognizes the colour of the objects by examining the light reflected from outside the items. Colour sensors are being used in various industries, including food and beverage. These sensors are broadly utilized in purchaser hardware for backdrop illumination control and show adjustment.
- **Air Quality:** Next is the Air quality sensor. It Senses the amount of NH3, alcohol, and co2 gas present in the air. This system requires a sensor that has excellent sensitivity to toxic gas in a wide range and has advantages, for example, a long lifespan, less expensive and a simple drive circuit. Air quality sensor is widely used in domestic gas alarm, industrial gas alarm and portable gas detector.
- **Ammonia gas:** Another essential factor is the ammonia gas sensor to sense the bacterial count of ammonia. For any liquid food, after some time, there is a continuous growth in bacterial count of ammonia, which is considered as harmful to consume. In this project, we need a gas sensor which has a dual signal output (analog output and TTL level output). Also, it has a long life and reliable stability.
- **pH Level:** Last but not least, A waterproof pH(potential of hydrogen) sensor. Every food has a certain pH level. It is essential to maintain a specific level of acidic and necessary for any healthy living. For the Edispotter, we need a waterproof pH(potential of hydrogen) sensor with less response time. Also, which can work under up-to 50 degrees Celsius.

Hence, these five factors are used to get accurate results for maintaining the quality of food.

Down the line, our sub-system senses the essential parameters of the surrounding environment, which affect the nutritional values of food items. Once the metrics are compared to standard threshold values for respective parameters later, those values converted into plotted graphs for the current and future analysis for the end-users. With the power of the Internet of Things, environmental factors affecting food storage can be monitored from anywhere and any device.

3.1 Architecture

Fig.1 explains the architecture of the Edispotter.

- **Food Sample:** Here food is considered to be a significant input in our Edispotter. It means the food can be raw or cooked items, which is to monitor for its healthy status.
- **Raspberry Pi:** This hardware component performs some tasks like data collection from the sensor, data analysis, data transfer in and out, which are some of the internal processes, as explained in the next paragraph.
- **Assorted Sensors:** Major environmental factors indulge in the spoilage of food samples such as temperature, humidity, Air Quality, Gas, pH(potential of hydrogen) level and so on. So individual sensors have used to detect such factors regarding the spoilage of food samples.
- **ESP32:** A hardware component that acts as a gear to raspberry pi processes and helps to convert analog signals to digital signals for smooth data transmission to the database.
- **Amazon Web Services Storage:** Cloud-based storage service used to stored data fetched from different sensors and store

it into the database for data analysis purposes.

- **Android Device:** For data visualization purposes and as a front-end component of our Edispotter, we have created an android based mobile application.

Below are some of the internal processes of our Edispotter:

- **Data collection:** Temperature, Color, Ammonia, pH(Potential of Hydrogen) level and Air quality parameters are used in the process for data fetching, with the hardware components such as Raspberry Pi and ESP32. Distinctive sensors sensed each parameter.
- **Data Transfer:** Messages are transmitted via MQTT(Message Queuing Telemetry Transfer) and HTTP(Hypertext Transfer Protocol) once the inputs are processed.
- **Data Storage:** Amazon Web Services(AWS) cloud storage powers Redis database to store the data in the key/value method.
- **Data analysis:** Based on the comparison of actual values and threshold values, decisions converted into final results.
- **Front-end visualization:** The android app organizes the culminate analysis to the end-user.

The food sample has considered as an input to the raspberry pi, which connected to the breadboard containing ESP32. Here core language is python for the creation of web server into the raspberry pi. Additionally, we have used Restful services for the execution of micro-services. As per figure 1, multiple sensors have connected to raspberry pi, which helps us to check the quality of food. Those sensors are focusing on every aspect required for analyzing the quality of the food. So far, we get to know that temperature, humidity, colour or light, pH(potential of hydrogen) value, air quality and ammonia are essential factors for any food, including drinks—the values from sensors transferred through MQTT along with HTTP protocol in the AWS storage. At last, data coming from sensors are compared with the raw values to get accurate results. Here, the comparison of the threshold value has made at AWS. For visualization purpose, we have implemented an android application which can be more feasible for the end-users.

3.2 Flow Diagram

Initially, the flow of the process starts from Food Sample to Android, as illustrated in Fig.2, which is as follows:

- **Food Sample:** Any eatable product considered as a food sample. In our case, an egg has taken as a food sample for the experimental setup.
- **Assorted Sensors:** Typically, we have used five sensors. Each sensor plays individual characteristics in collecting the vital parameters from the food sample. The following features assessed during the process, which are Temperature, Humidity, Light, Gas, Air quality and pH(potential of hydrogen) value.
- **Raspberry-Pi:** Processing achieved with the power of Raspberry-Pi. Where Secure Digital (SD) Card used for non-volatile memory and video output hooked to Android device. Also, it takes account of managing the input of sensors.
- **ESP 32:** This micro-controller is responsible for converting the analog to a digital signal and handling the pH sensor. Also, it provides Wi-fi(Wireless Fidelity) connectivity for transferring the data across the channels.
- **MQTT/HTTP:** Data transfer protocol MQTT/HTTP takes the responsibility of transferring data from hardware to the database. Where, MQTT used for transferring the data and HTTP for client/server response.
- **Redis-Amazon Web Services:** Amazon Web Services(AWS) provides an in-memory data store and cache service, which acts as a Platform as a Service (PaaS), and the Redis database has used to store the data in a key/value method for the in-memory cache.

- **Data Analysis:** Data has retrieved from the database, and decisions have made as per Algorithm 1. On top of the data set, visualization made for the result analysis.
- **Android:** Finally, the processed data from all the sections pushed to the android app, which provides a cumulative analysis of the various arguments for the given food sample.

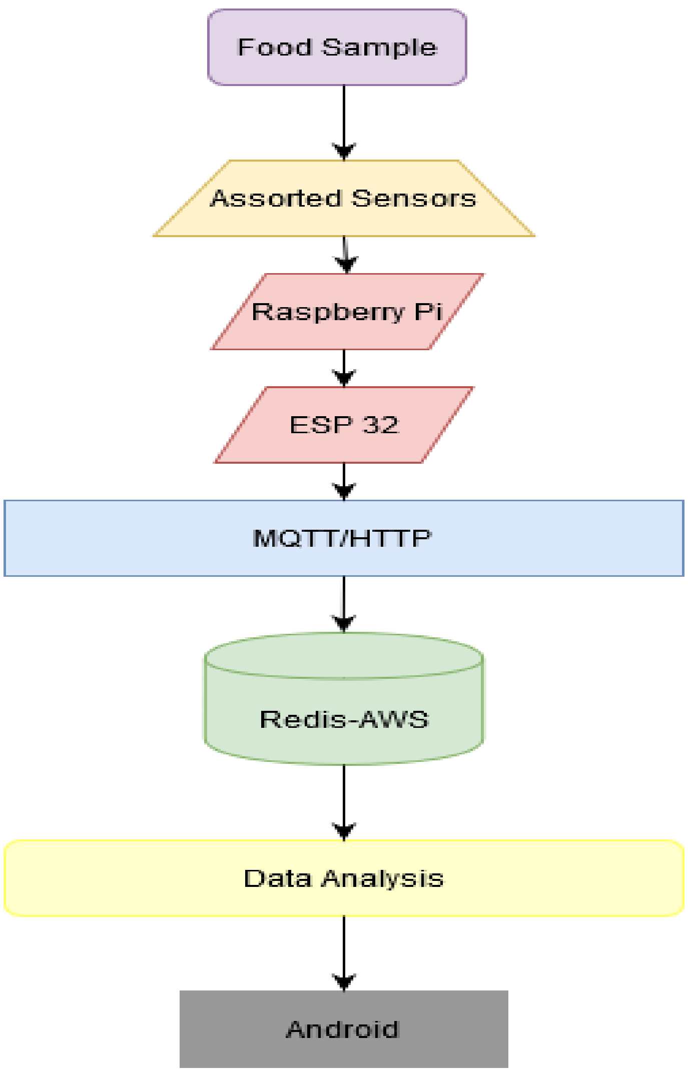


Fig.2: Flowchart

As shown in algorithm 1, we have taken two parameters, mainly. One is the actual value, and another is a predefined value, where predefined values vary with every food item. The main aim to take two parameters is to get the status of food, which is been evaluated in Amazon Web Services(AWS) storage. The formula is been described in the algorithm. If actual value is higher or lesser than a predefined value, then it gives negative feedback as food is not edible to eat, and when the actual value is the same as predefined values, then it shows positive feedback as food is edible to eat.

Finally, so after the connection is established, we are now requesting sensors to take readings and storing it into the database. After this, we can see the sensor fetches the data onto the android device display.

Algorithm 1: Algorithm of Edispotter

```
Request from Device;
while do
    Check Sensors;
    if Sensors≠True then
        Sensor Error;
    else
        Start the Sensor;
while do
    Readings measured;
    Activate sensors;
    Take readings;
    if Readings = True then
        Insert into Redis database in
          AWS;
    else
        Reading error;
while do
    Parameters Analysis;
    if Actual Value<Predefined Value ||
      Actual Value>Predefined Value then
        NOT Edible food;
    else
    Actual Value==Predefined Value
    Edible food;
```

For the algorithm of Edispotter, we have used python as a simulator in PyCharm IDE(Integrated Development Environment). We received output as Edible food for the algorithm, and values are recorded in the database.

It is essential to differentiate the Edispotter with the existing systems. Table.2 demonstrates the difference of flaws in the current system, and to overcome the weaknesses, and it contains features of the proposed method as well. MyIPM [53] is the android application that provides information to prevent spoilage of fruits. Open food facts [54] is the system that scans the bar-code of the food item. But there is no use for the food items without bar-code. Food standards and quality control is a non-interactive system, which shows all needful information about food standards and the quality of food. Yuka [55] is the application of a food scanner and cosmetic scanner. This system scans the food and also gives information about how to prevent spoilage of food.

Existing System	Flaws in the Existing system	Proposed EdiSpotter System
1) MyIPM	- It does not have any system which senses fruits. It just provides information to prevent food spoilage. - It is limited to fruits. - It has limited storage for storing the information.	- Edispotter can scan food providing real-time data representation for early detection of food spoilage. - It can sense fruits, milk, meat etc. - Wide storage range with AWS storage
2) Open Food Facts	- It requires a barcode. - It gives insufficient information to the user. - It does not provide the edibility of food.	- It does not require a barcode. - It gives the proper status of food to a user. - It provides the edibility of food by comparing the scanned food data to predefined values.
3) Food Standards & Quality Control	- No user interaction - It does not provide real-time data to the user. - No data can be added manually	- The system has throughout user interaction from sensing food to the generated result. - It provides real-time data to a user on the android app with graphical representation. - It can manually enter any food name with the food connected to sensors, which senses the freshness.
4) Yuka	- Response time is very long - The process is lengthy, as all the details of food are added manually.	- Response time is comparatively short. - Sensors automatically sense everything, which is not a lengthy process.

Table 2: Difference Between Existing System and Edispotter

3.3 Limitations

1) Currently, Edispotte r doesn't support iPhone users because it is developed as an android application.
2) The Edispotter kit is relatively compact. Hence it is not advisable for industries because industry set-up requires large-scale hardware requirements.
3) Established WiFi connection needed to transfer the data from raspberry pi and ESP32 to connect the Cloud server for the analysis.
4) More extensive support required to convert the prototype model into a production product, which includes manufacturing cost, labour cost, marketing team and miscellaneous expenses.
5) Edispotter needs the dependency of Android mobile phones to generate the results.

4 Experimental Results

4.1 Used Hardware Components

We did this particular experiment using Raspberry pi 3B+. Pi has a Quad-core 64-bit processor clocked at 1.4GHz. It also has 1GB LPDDR2 SRAM and Bluetooth 4.2 / BLE. Many factors are considered to select the hardware. Firstly the size of Raspberry pi is small as a credit card. Which makes is handy. It works like a regular computer at a low price. Though there are some limitations, it cannot run X86 operating system because of its processor. It can fill in as a PC, yet one can't supplant it. Let's talk about another component, which is ESP32. For this experiment, we have used esp32 for pH(potential of hydrogen) sensor. In which esp32 works as a micro-controller and converts the analog signals into a digital one. ESP32 is a progression of minimal effort, a low-power framework on a chip micro-controllers with coordinated WiFi and dual-mode Bluetooth. The most concerning issue of the ESP32 chip is that it can't be dependably reset into an anticipated starting state. Also, the firmware sometimes crashes randomly.

Talking about the sensors, we have used DHT11 for sensing temperature and humidity. It is a trendy and low-cost digital sensor available in the market. It is moderately easy to utilize, yet requires exact planning to recover the information accurately. One limitation of this sensor is that you can get new data from it no more regularly than once every 1 or 2 seconds. For sensing the colour of food, we have used a TSL2561 light sensor for this experiment. It has patented dual-diode architecture and I2C digital interface. The sensor enables operation in IR(Infrared Radiation) light environments and allows darkroom to high lux sunlight operation. Though it only works well with low power devices since the current draw is low.

The concentration of ammonia gas is high in spoiled food. To check the freshness of the food, we have used the MQ137 ammonia gas sensor. It has excellent affectability to NH3 gas in full range and has focal points, for example, long life expectancy, ease and primary drive circuit. It is generally utilized in local NH3 gas alert, mechanical NH3 gas spillage caution, convenient NH3 gas identifier. Though it is relatively inaccurate to get decent ppm reading, it is more useful to detect the presence of NH3 rather than get exact levels. The other drawback is that it has a very long warm up time. For maintaining proper hygiene, the quality of air is an essential factor. Here we have used the MQ135 air quality sensor, which is suitable for measuring NH3, NOx, Alcohol, Benzene, Smoke and CO2. It has fast response time and high sensitivity. It has a long life and available with low-cost in the market. Though it has some drawbacks, it can cause prone false alarms. Also, it is not recommended for areas where CO and CO2 produced the functions.

Every food has a certain pH(potential of hydrogen) level. And it is essential to maintain the pH level in the human body. To check the pH level of food, we have used the I2C(Inter-Integrated Circuit) waterproof pH sensor. As we have to sense the pH of liquid food, we need a waterproof detector. Its detectable concentration range is pH 0-14. The reaction time is under 5 seconds. It gives accurate results under -10 to 50 degree Celsius temperature. One major drawback is the output of the sensor is analog. While all other sensors provide a digital output, so for this, we have used ESP32, which helps to convert the analog output into a digital one.

4.2 Experimental Setup

The fig.3 shows the experimental setup for this project. An egg is considered as an input for this experiment. The hardware devices are the Raspberry Pi 3B+, ESP32 [56] and different sensors(DHT11 [57], TSL2561 [58], MQ137 [59], MQ135, I2C [60]). The sensors are used to check the quality of food by measuring various environmental factors. The data is transferred using MQTT [61]/HTTP protocol from hardware to database where we have used Redis service installed in Amazon Web Services(AWS) cloud to get the final results on an android app. The data analysis function plays a significant role to make decisions as per the Algorithm 1. A power supply is also needed to the Raspberry Pi 3B+ board through the USB cable from PC or by DC adaptor.

Fig.3: Experimental Setup

Here we have used raw egg for this experiment—this demonstration is done for four days. The values are coming from sensors then compared with raw values using Amazon Web Services(AWS) storage. These values are then processed to find the temperature, humidity, pH value and air quality of the raw egg. The output displayed in the android device, which covers analysis using graphs and other required modules.

Fig.4 shows the pin-out diagram of the raspberry pi 3B plus model, which has a 40-pin GPIO (General Purpose Input Output) header. In this header, there are two types of voltage pins found in which two are of 5V pins and two of 3.3V pins. Along with that, it has eight

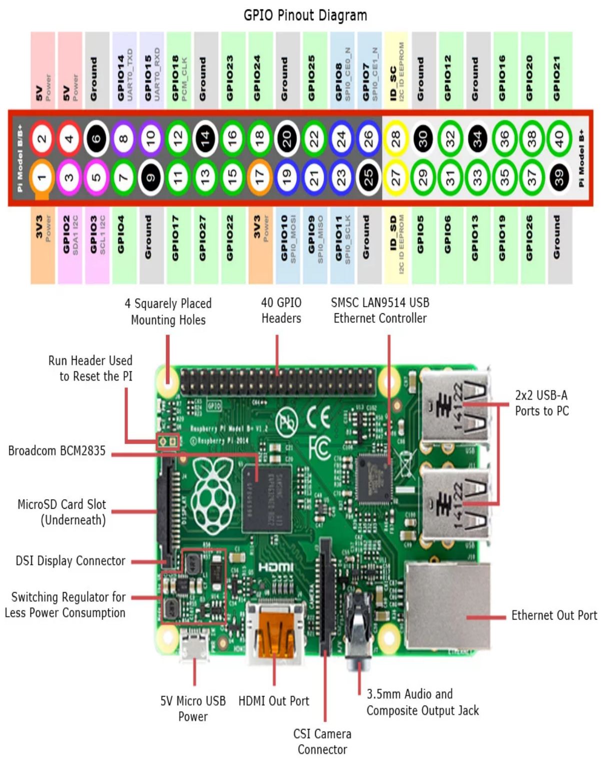


Fig.4: Raspberry Pi Pin-Out Diagram

ground pins (0V) as some of the sensors need to connect to ground voltage also. A GPIO pin as an output pin can be set to high (3V3) or low (0V). This GPIO pin further classified into four categories: PWM (Pulse-Width Modulation), Serial Pins, SPI (Serial Peripheral Interface), I2C (Inter-Integrated Circuit).

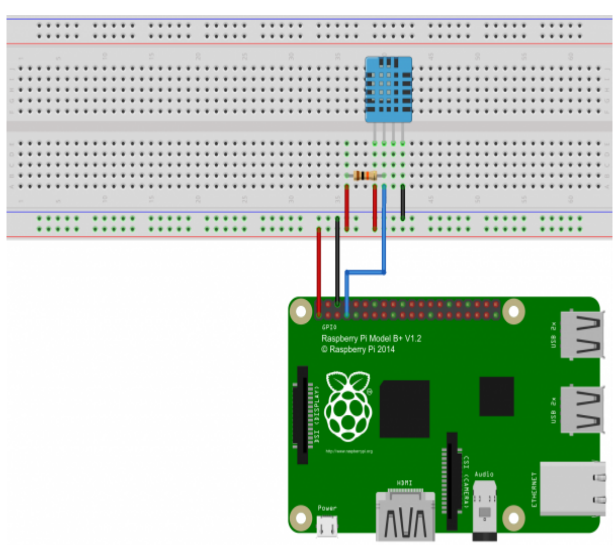


Fig.5: DHT11 Temp-Humid Sensor Connection

Figure 5 shows the integration of DHT11 temperature and humidity sensor with raspberry pi. So, we have connected the three pins of DHT11 to pin 2, 3 and 6 as input, output and grounding to Raspberry Pi Board, respectively. As explained earlier, this sensor detects the temperature and humidity of the food we sensed.

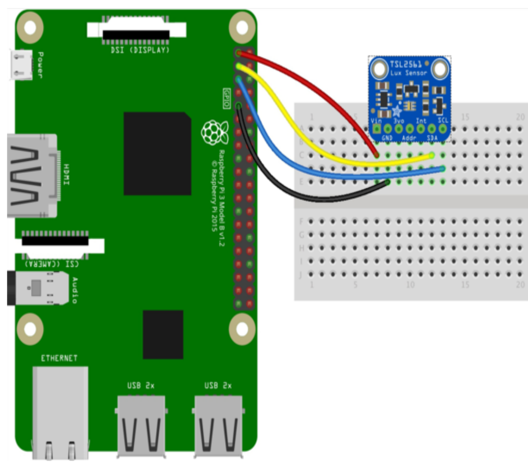


Fig.6: TSL2561 Light Sensor Connection

Figure 6 shows the designation of the TSL2561 light sensor with raspberry pi. For TSL2561, we have use pins 1, 5 and 9 as input, output and grounding to the header, respectively. As explained earlier, this sensor detects the luminosity of light so that we can get the food colour.

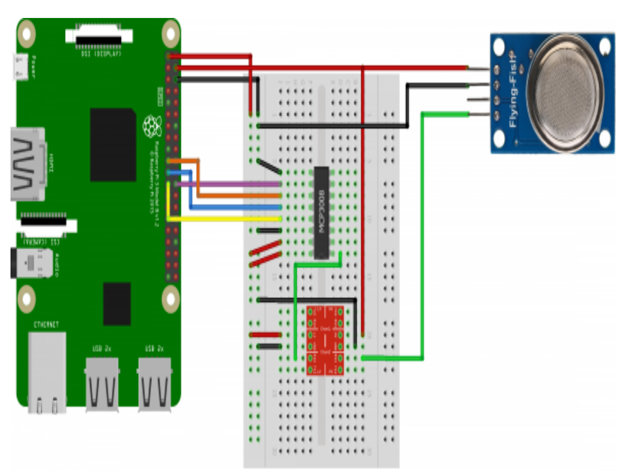


Fig.7: MQ135 Air Quality Sensor Connection

Figure 7 shows the connection of the MQ135 air quality sensor with raspberry pi. For this sensor, we have used 4,6 and 15 as input, output and grounding connected to board, respectively. As explained earlier this sensor detects the AQI (Air Quality Index) of food.

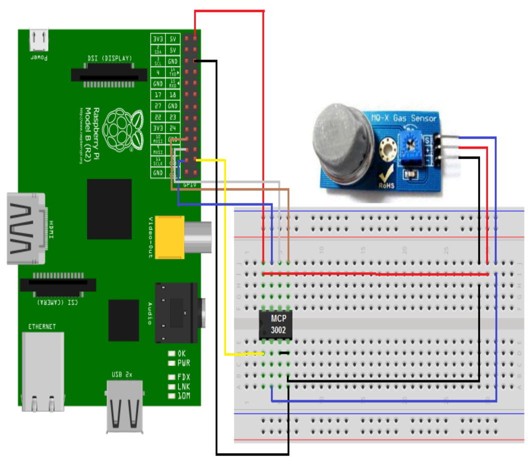


Fig.8: MQ137 Ammonia Sensor Connection

Figure 8 shows the connection of the MQ137 Ammonia Gas sensor with raspberry pi. Here we have used pins 36, 2 and 39 as input, output and grounding, respectively. As explained earlier, this sensor detects the ammonia gas emitted by food when it starts to get rotten.

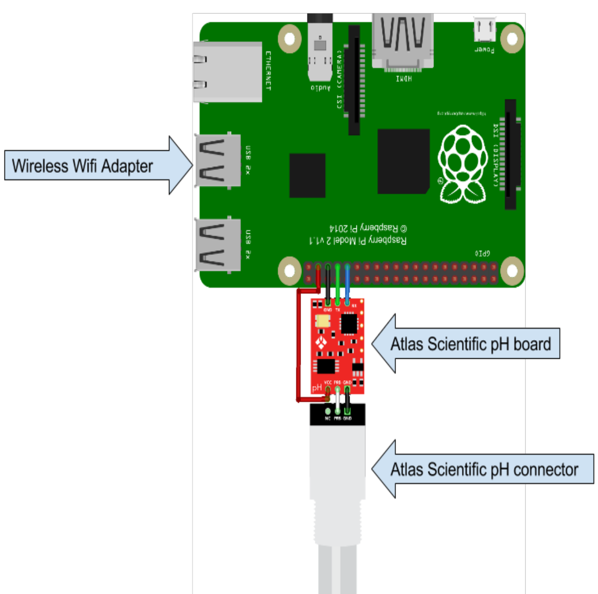


Fig.9: I2C pH Sensor Connection

Figure 9 shows the connection of the I2C (Inter-Integrated Circuit) pH sensor with raspberry pi. For this, we have used 27 as input pin 28 as output pin in and 25 as a ground pin. As explained earlier, this sensor detects the pH(potential of hydrogen) Level of food so that we can determine the acidity or base or neutral values range from 0 to 14.

4.3 Result Analysis

For Edispotter demonstration, we have used a raw egg to monitor for four days—the values of each sensor stored in Amazon Web Services(AWS) storage.

We have used Raspberry-Pi and Esp 32 for hardware, whereas Python and Kotlin for programming. For testing, we have made a comparison with the raw values and assumptions are made in the Android application to decide the status of the food.

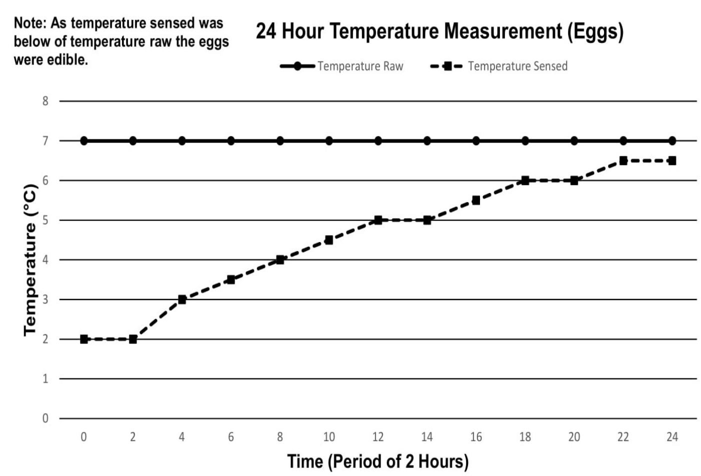


Fig.10: Temperature vs Time of An Egg Using Edispotter System

On the very first day, we made a comparison for 24 hours. As shown in fig.10, one significant factor affecting the spoilage of food is temperature. Here in this, we have considered the raw values of an egg as well as sensed values coming from raspberry pi using sensors. The solid line shows the raw value, which is stable with time. The dotted line explains the real-time value from Raspberry Pi. For the egg, the predefined value for temperature is 7 degrees Celsius or below.

As you can see, after 4 hours, the temperature is 3 degrees Celsius, and it is giving us a slight change every 2 hours. Finally, after 24 hours, we got a value of 6.5. For the egg, the sensed value should be below the threshold value. Here we can see sensed value is below the threshold. So the egg is edible if we just focus on temperature. Now let's talk about other factors as well.

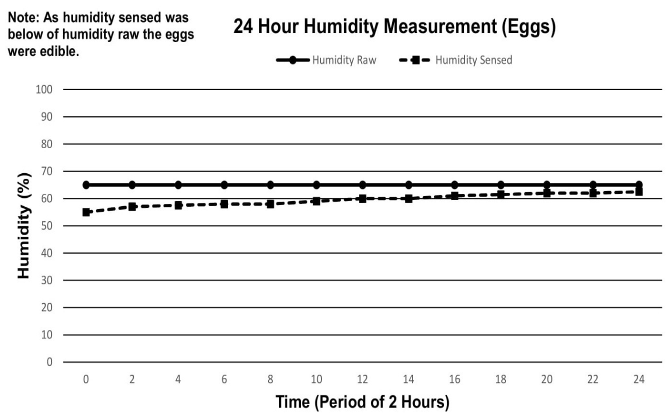


Fig.11: Humidity vs Time of An Egg Using Edispotter System

As shown in fig.11, the graph is for Humidity vs Time. The readings for 24 hours are pretty steady. As demonstrates in the chart, the solid line is for raw value, and the dotted line stands for values coming from sensors. After 24 hours, we are gathering the final output, which is 62.5 percentage. For the egg, the value of humidity is 65 percent or below. Here we are getting 62.5 value after 24 hours, which says the egg is edible with accurate humidity.

In fig.12, it shows the air quality of egg versus time which is a measured period of 24 hours. The readings here show a variation in sensed values as it starts with 12 AQI(Air Quality Index), and every hour there is a slight change. Here AQI means Air Quality Index, which is a unit of air quality. The solid line stands for raw value, and the dotted line stands for sensed values taken from sensors. After the last hour of the test, we got the output as 43 AQI. As for egg to be good, The sensed values should be below raw value, here raw value

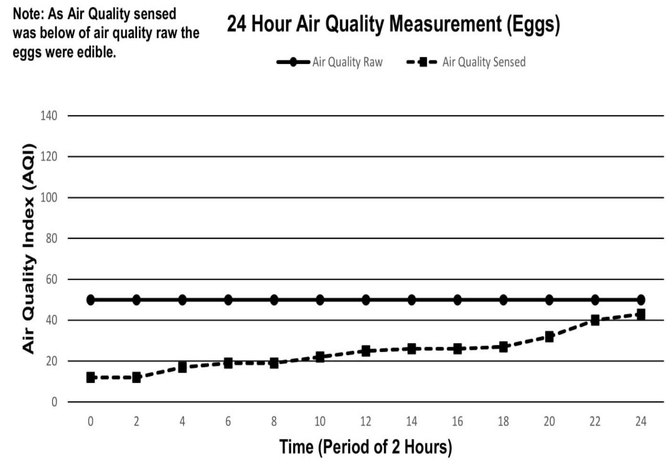


Fig.12: Air Quality vs Time of An Egg Using Edispotter System

after 24 hours is 50 AQI, and the sensed value is 43 AQI. So we can state that the egg is under good Air quality, and it is edible.

So, at last, we measured the pH(Potential of Hydrogen) value of eggs for 24 hours, and we got the final output, which we can see in fig.13. As earlier said, the solid line shows the raw pH values, and the dotted lines show the sensed pH values. So, in the end, we got 7.9 as the final pH value from the sensor. Where the raw value of pH is 7.9 too, and the value we got from the sensor after 24 hours is also 7.9. so we can comment that according to the values we got, the egg is edible with the required pH level.

In addition to the calibration tests, the sensors were evaluated during long-term measurements (lasting four days) to verify their stability and functionality. These environmental tests carried out in normal room conditions, and temperature, humidity, air quality and pH values were measured. Fig.14 shows the measurements for four days at a measuring interval of 6 hours. First of all, the change in temperature shown. The temperature in the standard room was around 4 degrees Celsius.

During these tests, we found ups and downs in the temperature as after 24 hours, we got 5 degrees Celsius, and then after 12 hours, the temperature decreases with a difference of

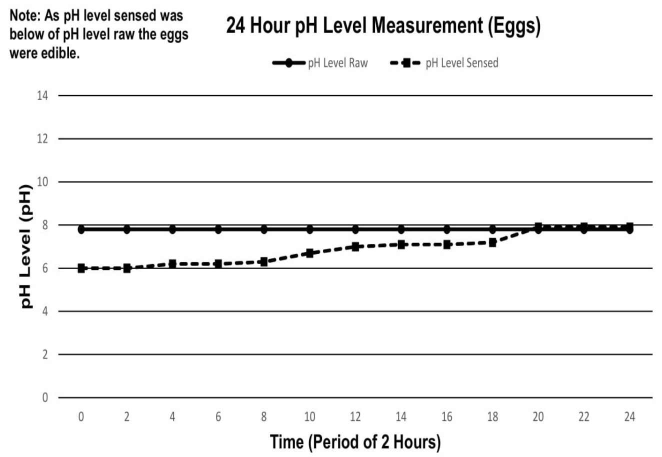


Fig.13: pH vs Time of An Egg Using Edispotter System

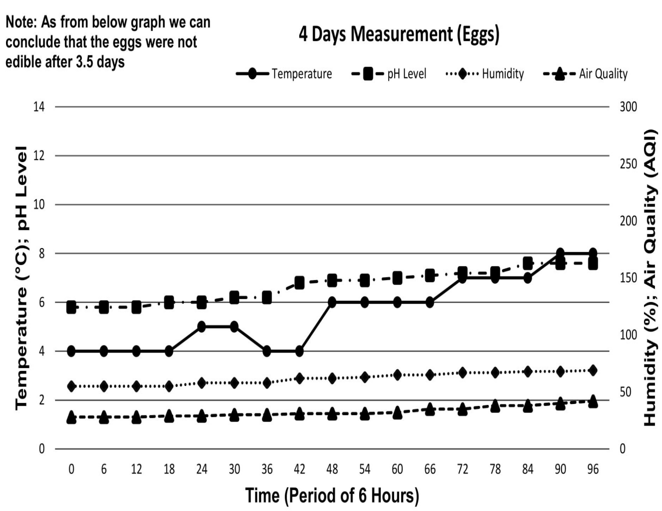


Fig.14: 4 Days Measurement of An Egg Using Edispotter System

1 degree Celsius, i.e. 4 degrees Celsius. Then gradually, there is a rise in temperature after 42 hours. Secondly, considering the pH factors at each hour, there is a bit rise in pH values, and after 96 hours, we got eight pH levels.

Thirdly, there was not much growth in humidity and air quality after every 6 hours. These results demonstrate that the current system can monitor accurate results, and we can say that after 3.5 days, the eggs have started getting rotten as after 96 hours, we got temperature as 8 degrees Celsius, humidity as 70 percentage and pH as 8. Comparing this all values with the predefined values of each factor, we can conclude that eggs were not edible as they were above the raw values.

4.4 Android Application

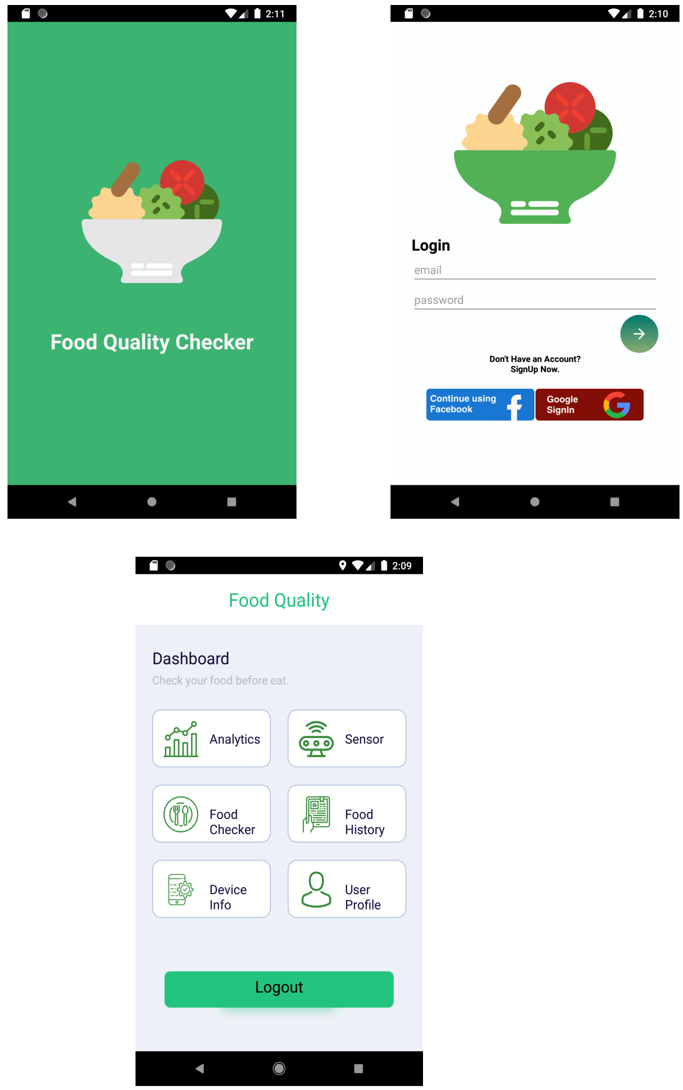


Fig.15: Screenshots of Android Application

The above fig.15 shows the android application, Which we consider making for visualization purposes and making Edispotter user friendly. The very first screenshot is of the splash screen that displays the application name. Whenever you click on the app icon and open the application, a splash screen will occur. The second screenshot is of login and signup in which users can log in if they have already registered, and sign up if they are a new user by giving their personal information such as name, email id, age, and phone number. We have added an extra feature of login with Facebook or Google for our end users. Now, we will talk about the dashboard screen, which contains User Profile, Sensor details/configuration, Food checker, Food history, Device info and analytics. Users can view their information in a user-profile module. The hardware information such as raspberry pi and Esp32 status, its model number, and other technical details are there in Device info. The condition of sensors, whether the sensors are active or not, can be seen in the sensor details module. The sensed data from raspberry pi stored in food history with individual food Id, and the real-time data for any food shown in the food checker module containing all the parameters, such as pH(potential of hydrogen) level, air quality, temperature, humidity and ammonia contamination. Where analytics provides real-time and hourly graphs for each factor individually.

To develop the android application, we have used an android studio on our windows operating system. Android studio is a suitable integrated development environment(IDE) for google's android operating system, which provides an excellent platform for data analysis [62]. We have developed a mobile app using the KOTLIN programming language. Android studio facilitates many features such as fast emulator, intelligence code editor, instant app run etc.

Majorly, our model solves a dual scenario. Firstly, food consumers can able to detect the status of the food material from the place where the product consumed. Secondly, our prototype can utilize in the restaurants(For example, KFC, McDonald's etc.,) to sense the entire food products through which cumulative graph generated in the store dashboard, which aids the customer in deciding the condition of the food. Comparatively, the existing models are mostly factory oriented food monitoring. In contrast, our prototype facilitates personal use for every individual user at an affordable cost, which can be manufactured in less than a hundred dollars, once it moves into the market. Crisply, Our prototype can compactly bring into a 6-inch device, which will be similar to a mobile phone. Hence it turns to be user-friendly and portable. By upbringing, similar food measures will help to prevent COVID-19 and other deadly diseases in mere future.

5 Product Analysis

After all research on the existing system and comparison with the proposed method, Edispotter stands out based on many features. Firstly, talking about the main features, considering multiple environmental factors that affect the quality of food. As discussed earlier, the freshness of food depends on temperature, humidity, pH(potential of hydrogen) level, and the quality of air. In day to day lives, people eat outside without knowing the freshness of the food item. In this scenario, if customers have Edispotter, then they can use it before consuming any food item from the restaurant, which can make their life easy and healthy. Apart from that, we have used an android application that shows real-time data of each food item, considering every factor in mind. Secondly, Amazon Web Services storage has used to manage large amounts of data. Though to make this happen, users must need internet connection all the time to sense the food through raspberry pi with different sensors and to send data to android devices.

Nowadays, food hygiene is essential, and systems that check the freshness of food are helpful too. Edispotter aims to give real-time analysis to users and decrease the number of health issues by consuming rotten food. If the government makes a policy for each food industry to put a display board that shows real-time data of temperature, humidity, pH(potential of hydrogen) Level and air quality of food hourly, then; as a result, customers will look at the food items and their freshness. At that time, they can decide whether it's healthy for them to consume or not. Many famous food industries like Tim Hortons, Starbucks, KFC, McDonald's etc. can use this system to attract their customers by giving them confidence that what they are buying is fresh and edible. This product could also be used in restaurants where customers can have that system handy with them, and they can check the status of food whenever it arrives at the table. To add to this, in restaurants, not only customers but kitchen staff can also use this and check the quality of food before serving to customers.

The cost of the Edispotter will be based on the hardware that we have used and the cloud storage that we bought from amazon web services(AWS). So the overall cost we spent on equipment was around 180-200 CAD, which includes the value of Raspberry Pi, ESP32 microcontroller, the different sensors and cloud instances running in AWS.

6 Conclusion

In a nutshell, humankind facing lots of disease through the food which we consume. So after researching the current food quality monitoring projects and after reading multiple articles, it is found that technology has created a significant impact on our life. In this paper, the prototype design proposed, and the name of our model is "Edispotter." To make it a bit user friendly, we have also created an android app that can show the readings in a graphical way as well as numeric. Every task can be done remotely in an effortless way. The objective of the Edispotter is to minimize the health issues that may occur by consuming bad food, which looks useful to the customer but which is not edible. Soon, implementing this method into our daily life aids us in consuming healthy food and in a way, it protects from deadly diseases like COVID-19.

7 Acknowledgment

We might want to communicate our profound and sincere appreciation to our supervisor, Dr. Hosam El-Ocla, Division of Computer Science, Lakehead University. Originating from the other nation, it is troublesome. It can get overpowering some of the time, yet his understanding, persistence, support and proper direction have demonstrated priceless in the arrangement of this project. We truly value his open-entryway strategy and day by day gatherings, which genuinely helped us to seek our project, and specifically, for testing our previously established inclinations and extending the comprehension of our chosen field. We could not imagine having a superior counsellor and guide for the master study. It has been a genuine pleasure working with him.

References

[1] J. R. Balbin, J. T. Sese, C. V. R. Babaan, D. M. M. Poblete, R. P. Panganiban and J. G. Poblete, "Detection and classification of bacteria in common street foods using electronic nose and support vector machine," 2017 7th IEEE International Conference on Control System, Computing and Engineering (ICCSCE), Penang, 2017, pp. 247-252.

[2] R. Blank, P. Vinayaka, M. Tahir, M. Vellecoop, W. Lang, "Optical Sensor System for the Detection of Mold", Busan, 2015.

[3] R. Blank, P. Vinayaka, M. Tahir, M. Vellecoop, W. Lang, "Comparison of several optical methods for an automated fungal spore sensor system concept", IEEE Sensors Journal, 2016.

[4] R. Blank, P. P. Vinayaka, M. W. Tahir, J. Yong, M. J. Vellekoop and W. Lang, "Development of a Fungal Risk Monitor for the next generation of intelligent container-saper," 2016 IEEE SENSORS, Orlando, FL, 2016, pp. 1-3.

[5] M. Li, H. Wang, L. Sun, G. Zhao, X. Huang, "Application of electronic nose for measuring total volatile basic nitrogen and total viable counts in packaged pork during refrigerated storage", J. Food Sci., vol. 81, no. 4, pp. 906-912, Apr. 2016.

[6] S. F. Liu, A. R. Petty, G. T. Sazama, T. M. Swager, "Single-walled carbon nanotube/metalloporphyrin composites for the chemiresistive detection of amines and meat spoilage", Angewandte Chem. Int. Ed., vol. 54, no. 22, pp. 6554-6557, May 2015.

[7] S. Li, S. Chen, B. Zhuo, Q. Li, W. Liu and X. Guo, "Flexible Ammonia Sensor Based on PEDOT:PSS/Silver Nanowire Composite Film for Meat Freshness Monitoring," in IEEE Electron Device Letters, vol. 38, no. 7, pp. 975-978, July 2017.

[8] A. Zakeri, M. Saberi, O. K. Hussain and E. Chang, "An Early Detection System for Proactive Management of Raw Milk Quality: An Australian Case Study," in IEEE Access, vol. 6, pp. 64333-64349, 2018.

[9] Y. Liu, "Wireless Information and Power Transfer for Multirelay-Assisted Cooperative Communication," in IEEE Communications Letters, vol. 20, no. 4, pp. 784-787, April 2016.

[10] "WHO Director-General's opening remarks at the media briefing on COVID-19 - 11 March 2020". World Health Organization (WHO) (Press release). 11 March 2020.

[11] S B Prapulla, G Shobha, T C. Thanuja, " Smart Refrigerator Using Internet Of Things. Journal of Internet of Things ", Journal of Multidisciplinary Engineering Science and Technology (JMEST), 2015.

[12] P. R. Kadam and K. P. Shinde, "Real Time Milk Monitoring System," 2018 Fourth International Conference on Computing Communication Control and Automation (ICCUBEA), Pune, India, 2018, pp. 1-5.

[13] S.G. Galande, B. Jhadav Dnyaneshwar, D. Mhase Mayur, J. Manakar Rahul, "The Detection Of Urea Sugar Sodium Chloride And Measurement Of Ph Parameter In The Milk By ing Arm Processor", International Journal of Informative Futuristic Research, vol. 2, no. 6, pp. 1824-1827, 2015.

[14] Hatsun Agro Milking the IoT Opportunity in Indian Dairy, 2017, [online] Available: https://rctom.hbs.org/submission/hatsun-agro-milking-theiot-opportunity-in-indian-dairy/.

[15] P. S. Kajal, K. Y. Shivashkti, R. B. Shivangi, B. G. Arati, R. K. Pooja, "IoT based detection of microbial activity in raw milk by using Intel Galileo Gen II", Int. Res. J. Eng. Technol., vol. 4, no. 1, pp. 487-491, 2017.

[16] S. De Silva, K. Kanugala, N. Weerakkody, "Microbiological quality of raw milk and effect on quality by implementing good management practices", Procedia Food Sci., vol. 6, pp. 92-96, 2016.

[17] K. Ruangwittayanusorn, D. Promket, A. Chantiratikul, "Monitoring the hygiene of raw milk from farms to milk retailers", Agricult. Agricult. Sci. Procedia, vol. 11, pp. 95-99, 2016.

[18] S. C. Murphy, N. H. Martin, D. M. Barbano, M. Wiedmann, "Influence of raw milk quality on processed dairy products: How do raw milk quality test results relate to product quality and yield?", J. dairy Sci., vol. 99, no. 12, pp. 10128-10149, 2016.

[19] M. Li, H. Wang, L. Sun, G. Zhao, X. Huang, "Application of electronic nose for measuring total volatile basic nitrogen and total viable counts in packaged pork during refrigerated storage", J. Food Sci., vol. 81, no. 4, pp. 906-912, Apr. 2016.

[20] S. Li, S. Chen, B. Zhuo, Q. Li, W. Liu and X. Guo, "Flexible Ammonia Sensor Based on PEDOT:PSS/Silver Nanowire Composite Film for Meat Freshness Monitoring," in IEEE Electron Device Letters, vol. 38, no. 7, pp. 975-978, July 2017.

[21] L. Feng, W. Tang, J. Zhao, R. Yang, W. Hu, Q. Li, R. Wang, X. Guo, "Unencapsulated air-stable organic field effect transistor by all solution processes for low power vapor sensing", Sci. Rep., vol. 6, pp. 20671, Feb. 2016.

[22] Q. Lin, H. Wang, X. Pei and J. Wang, "Food Safety Traceability System Based on Blockchain and EPCIS," in IEEE Access, vol. 7, pp. 20698-20707, 2019.

[23] W. Zhang, P. Dong, F. Lao, J. Liu, X. Liao, and J. Wu, "Characterization of the major aroma-active compounds in Keitt mango juice: Comparison among fresh, pasteurization and high hydrostatic pressure processing juices," Food Chem., vol. 289, pp. 215–222, Aug. 2019.

[24] B. Yu, P. Zhan, M. Lei, F. Zhou and P. Wang, "Food Quality Monitoring System Based on Smart Contracts and Evaluation Models," in IEEE Access, vol. 8, pp. 12479-12490, 2020.

[25] L. Zhang, F. Tian, "Performance study of multilayer perceptrons in a low-cost electronic nose", IEEE Trans. Instrum. Meas., vol. 63, no. 7, pp. 1670-1679, Jul. 2014.

[26] X. Yin, L. Zhang, F. Tian and D. Zhang, "Temperature Modulated Gas Sensing E-Nose System for Low-Cost and Fast Detection," in IEEE Sensors Journal, vol. 16, no. 2, pp. 464-474, Jan.15, 2016.

[27] Guidelines for Drinking-Water Quality,May 2011,[online] Available: http://www.who.int/water_sanitation_health/publications/dwq-guidelines-4

[28] Xiao, M., Bao, F., Wang, S. et al. Water quality assessment of the Huaihe River segment of Bengbu (China) using multivariate statistical techniques. Water Resour 43, 166–176 (2016).

[29] Ritota, M., Manzi, P. Melamine Detection in Milk and Dairy Products: Traditional Analytical Methods and Recent Developments. Food Anal. Methods 11, 128–147 (2018).

[30] N. A. Cloete, R. Malekian and L. Nair, "Design of Smart Sensors for Real-Time Water Quality Monitoring," in IEEE Access, vol. 4, pp. 3975-3990, 2016.

[31] T. de Almeida Oliveira and E. P. Godoy, "ZigBee Wireless Dynamic Sensor Networks: Feasibility Analysis and Implementation Guide," in IEEE Sensors Journal, vol. 16, no. 11, pp. 4614-4621, June1, 2016.

[32] F. Fleurat-Lessard, "Integrated management of the risks of stored grain spoilage by seedborne fungi and contamination by storage mould mycotoxins—An update", J. Stored Products Res., vol. 71, pp. 22-40, 2017.

[33] R. N. Dean, J. D. Craven, E. A. Guertal and K. A. Varnavas, "A PCB Sensor for Status Monitoring of Stored Food Stocks," in IEEE Sensors Letters, vol. 3, no. 4, pp. 1-4, April 2019, Art no. 6000604.

[34] R. N. Dean, F. T. Werner, "A PCB environmental sensor for use in monitoring drought conditions in estuaries", J. Microelectron. Electron. Packag., vol. 13, pp. 182-187, 2016.

[35] Lee, J., Jang, C., Choi, C. et al. High-shock silicon accelerometer with an over-range stopper. J Mech Sci Technol 30, 1817–1824 (2016).

[36] Lian-min, C., Ya-zhu, Z., Shi-jiao, S. et al. Structure design and test of MEMS thermocouple infrared detector. Microsyst Technol 24, 2463–2471 (2018).

[37] L. Zhang, Y. Liu and P. Deng, "Odor Recognition in Multiple E-Nose Systems With Cross-Domain Discriminative Subspace Learning," in IEEE Transactions on Instrumentation and Measurement, vol. 66, no. 7, pp. 1679-1692, July 2017.

[38] X. Yin, L. Zhang, F. Tian, D. Zhang, "Temperature modulated gas sensing E-nose system for low-cost and fast detection", IEEE Sensors J., vol. 16, no. 2, pp. 464-474, Jan. 2016.

[39] A. Polak, F. K. Coutts, P. Murray and S. Marshall, "Use of hyperspectral imaging for cake moisture and hardness prediction," in IET Image Processing, vol. 13, no. 7, pp. 1152-1160, 30 5 2019.

[40] B. Leblon, "Overview on sensing technologies for real-time monitoring of wood properties", IASIM – 6th Conf. in Spectral Imaging, 2016.

[41] K. Takechi et al., "Demonstration of Detecting Small pH Changes Using High-Sensitivity Amorphous InGaZnO4 Thin-Film Transistor pH Sensor System," in IEEE Transactions on Electron Devices, vol. 64, no. 2, pp. 638-641, Feb. 2017.

[42] Kang, J., Park, J., Park, K. et al. Temperature control of micro heater using Pt thin film temperature sensor embedded in micro gas sensor. Micro and Nano Syst Lett 5, 26 (2017).

[43] N. Javed, A. Habib, Y. Amin, J. Loo, A. Akram and H. Tenhunen, "Directly Printable Moisture Sensor Tag for Intelligent Packaging," in IEEE Sensors Journal, vol. 16, no. 16, pp. 6147-6148, Aug.15, 2016.

[44] H. Tsai et al., "Wearable Inverse Light-Emitting Diode Sensor for Measuring Light Intensity at Specific Wavelengths in Light Therapy," in IEEE Transactions on Instrumentation and Measurement, vol. 68, no. 5, pp. 1561-1574, May 2019.

[45] U. Jaimini, T. Banerjee, W. Romine, K. Thirunarayan, A. Sheth and M. Kalra, "Investigation of an Indoor Air Quality Sensor for Asthma Management in Children," in IEEE

Sensors Letters, vol. 1, no. 2, pp. 1-4, April 2017, Art no. 6000204.

[46] R. A. Rodríguez, P. Cammarano, D. A. Giulianelli, P. M. Vera, A. Trigueros and L. J. Albornoz, "Using Raspberry Pi to Create a Solution for Accessing Educative Questionnaires From Mobile Devices," in IEEE Revista Iberoamericana de Tecnologias del Aprendizaje, vol. 13, no. 4, pp. 144-151, Nov. 2018.

[47] G. Kim, S. Kang, J. Park and K. Chung, "An MQTT-Based Context-Aware Autonomous System in oneM2M Architecture," in IEEE Internet of Things Journal, vol. 6, no. 5, pp. 8519-8528, Oct. 2019.

[48] Colombo, P., Ferrari, E. Fine-Grained Access Control Within NoSQL Document-Oriented Datastores. Data Sci. Eng. 1, 127–138 (2016).

[49] Mercy, J.A., Vivolo-Kantor, A.M. Erratum to: The Centers for Disease Control and Prevention's (CDC) Youth Violence Prevention Centers: Paving the Way to Prevention. J Primary Prevent 37, 311 (2016).

[50] Kendall, P., Scharff, R., Baker, S. et al. Food Safety Instruction Improves Knowledge and Behavior Risk and Protection Factors for Foodborne Illnesses in Pregnant Populations. Matern Child Health J 21, 1686–1698 (2017).

[51] Bansal, S., Kumar, D. IoT Ecosystem: A Survey on Devices, Gateways, Operating Systems, Middleware and Communication. Int J Wireless Inf Networks (2020).

[52] Raspberry Pi. 2020. Raspberry Pi 3 Model B+ On Sale Now At Dollar35 - Raspberry Pi. [online] Available at: https://www.raspberrypi.org/blog/raspberry-pi-3-model-bplus-sale-now-35/.

[53] G. Schnabel, MyIPM Smartphone App Series. College of Agriculture, Forestry and Life Sciences. Clemson University, South Carolina, Clemson.edu, 2012. [Online]. Available: https://www.clemson.edu/extension/peach/commercial/diseases/myipmsmartphoneappseries.html/.

[54] S. Gigandet, World, Open Food Facts, 2012. Available: https://world.openfoodfacts.org/.

[55] Benoît, The mobile app that scans your diet and cosmetics, Yuka, 2014. Available: https://yuka.io/en/.

[56] Rototron.info. 2020. Raspberry Pi ESP32 Micropython Tutorial — Rototron. [online] Available at: https://www.rototron.info/raspberry-pi-esp32-micropython-tutorial/.

[57] Basics, C., 2020. How To Set Up The DHT11 Humidity Sensor On The Raspberry Pi - Circuit Basics. [online] Available at: https://www.circuitbasics.com/how-to-set-up-the-dht11-humidity-sensor-on-the-raspberry-pi.

[58] Instructables.com. 2020. Circuit Diagram. [online] Available at: https://www.instructables.com/id/Lux-Sensor-TSL2561-Raspberry-Pi/.

[59] Raspberry Pi Tutorials. 2020. Configure And Read Out The Raspberry Pi Gas Sensor (MQ-X). [online] Available at: https://tutorials-raspberrypi.com/configure-and-read-out-the-raspberry-pi-gas-sensor-mq-x/.

[60] Scientific, A. and Pi, C., 2020. Connecting Multiple Sensors To Raspberry Pi. [online] Hackster.io. Available at: https://www.hackster.io/atlasscientific/connecting-multiple-sensors-to-raspberry-pi-c780fd.

[61] Raspberry Pi Tutorials. 2020. Wireless Communication Between Raspberry Pi's Via MQTT Broker/Client. [online] Available at: https://tutorials-raspberrypi.com/raspberry-pi-mqtt-broker-client-wireless-communication/.

[62] Android Studio, designed specifically for Android development, 2013. [online] Available at: https://developer.android.com/studio/.

RASHMI PANKAJKUMAR TAILOR received a B.Tech degree in Information Technology from Gujarat Technological University, India, in 2017 and an M.Sc. degree in Computer Science from Lakehead University, Thunder Bay, ON, Canada, in 2020. Her areas of interest include Mobile Application Development, Big Data, Cloud computing, Front End Web Developer and Data Science.

KAMALAKANNAN KUMAR received a B.Tech degree in Information Technology from Anna University, Chennai, India in 2017 and an M.Sc degree in Computer science from Lakehead University, Thunder Bay, Canada, in 2020. His areas of interest include Big data, IoT, Data analysis and Data Science.

SMIT RAJESH PARIKH is pursuing an M.Sc. degree in the Department of Computer Science from Lakehead University, Thunder Bay, Ontario, Canada in 2020. He received his B.Tech Degree in Computer Science Engineering from Gujarat Technological University, India, in 2017. His current interest is in Data Science, Cloud Computing, Search Engine Optimization Web Developer.

Dr. Hosam El-Ocla received the M.Sc. degree in the Electrical Engineering Department of Cairo University in1996 and the Ph.D. degree from Kyushu University in 2001. He joined the Graduate School of Information Science and Electrical Engineering, Kyushu University, Japan in 1997 as a research student. He joined Lakehead University in 2001 as an Assistant Profes-

sor and has been an Associate Professor since 2007. His current main interests are in wireless sensor networks.