

IoT enabled industrial fault monitoring and prediction

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Abstract

Automation is now heavily used in the industry. Human effort is much reduced by implementation of an automation system that monitors and signals system faults that may arise. The number of devices that can be connected to the Internet of Things (IoT) is growing every day. With the aid of the IoT model, a hardware prototype will be developed that will automatically monitor industrial parameters such as humidity, temperature, fire, smoke, pressure, and sense motion, as well as generate alerts and alarms. Each parameter is continuously monitored using an application called Blynk. This proposed work will use IoT to provide information remotely about the current weather and gas concentrations in the plant via email. The collected information can also be used for predictive analysis. The idea behind this proposed work is to accumulate and visualize data about the various parameters utilized in industries by enabling IoT.

Keywords

IoT, Automation, Blynk, DHT11, Smoke, PIR

1. Introduction

The Internet of Things (IoT) [1] has a huge impact on every industry as well as in our day-to-day life. IoT can be categorized based on its intended use (such as in a smart city, smart devices, smart home, smart enterprise, and smart environment [1]), and depending on the application (individual or group of interconnected devices), in view of the convention utilized for Machine-to-Machine (M2M) communication. IoT products can be utilized (1) as a separate gadget or device, with the purpose of observing a machine in industries; (2) they have the ability to communicate with mobile phones; and (3) furthermore, in the case of a bunch of sensors mounted on IoT products, they converse with each other, to analyze raw data, analyze with the embedded software, and then set off the next occasion of interest. The manufacturing or industrial domain is one of the many areas wherein IoT could be utilized for predictive maintenance and for enhanced or improved safety metrics for laborers

in an industry environment [2,3]. Industrial Internet of Things (IIoT) [4] is the term used for IoT in the industrial sector, and it refers to using IoT features in industrial plants to improve and facilitate conventional manufacturing processes [1,4]. Innovation is being used and developed in an incredible manner. In a continuous cycle industry, it is difficult for personnel to track every parameter accurately and effectively. For instance, in the case of gas spills from the petroleum, oil, and gas industry, gas spillage is harmful for humans and for the environment, and can cause severe harm and damage to plants. In nuclear power reactors, the temperature in the heat exchanger must be kept within a particular range. If the temperature rises beyond a set point, it might lead to serious consequences. For devices that are placed in faulty locations [5], communication happens based on the IPV6 model, with each device receiving it in its own IP address. Using remote access via the Internet, an embedded system combined with web technologies will provide improved control. The use of web

development to operate these devices is a prestigious way. Web development facilitates remote access to device parameters and control based on parameters. Web application is used for monitoring and handling data. Electronics has made life easy for us. One of the approaches from electronics using IoT is fault detection. The entire model is built around embedded microcontrollers. Building a web control system allows for remote login and monitoring of parameters, making it easier to regulate and monitor the various parameters without causing severe damage. This proposed work is to monitor industries or manufacturing plants distantly for humidity, motion, temperature, and gas leaks. The proposed methodology utilizes Arduino and ESP8266 with sensors DHT11, MQ2, Passive Infrared (PIR), and BME280 (Bosch Sensortec). With the help of IoT, it will send the information from a distance about the current weather and gas concentrations in the plant via email. The program sets the boundaries and if the outcomes are not within the boundaries, it will send alerts with caution so that instant action can be taken to forestall the crisis situation. Blynk is used as a server and as an application (app) to read the data. The Blynk app collects data from the sensors wirelessly and stores it. In this methodology predictive analysis is applied. Predictive analytics uses many techniques from statistics, data mining, modeling, and artificial intelligence to machine learning. Using analytical tools, predictive analytics can spot small anomalies in machines.

In this article, the design of a monitoring system for industrial faults commenced with collecting data via sensors for 2–3 hr every day; after this the collected data were analyzed using predictive analytics.

II. Objective

The objective of the proposed system is to monitor the temperature, harmful gases, barometric pressure, and humidity and report the information on a device/cell phone. It will also report about the unsafe conditions for the workers.

A basic block diagram of the proposed work is shown in Figure 1. It uses IoT to provide

information remotely about the current weather and gas concentrations in the plant via email. The most recent innovation is constantly adapted and combined to accomplish an effective device that can be broadly utilized by all. According to recent statistics of the National Fire Protection Association (NFPA), an estimated 37,100 fires at manufacturing or industrial properties are recorded each year, resulting in 16 civilian deaths, 273 civilian injuries, and US\$1.2 billion worth damage of direct property. Manufacturing or industrial facility structure fires accounted for nearly two-thirds (65%), compared with all other structure fires (such as defense, industrial, agriculture, utility, and mining properties). So, if the device can recognize flammable gases and the odds of where fire and mishaps can happen, then it can prevent damage to life and property. Therefore, the proposed device is the apt solution to prevent such accidents.

III. Literature review

There are various studies based on IoT fault monitoring system, but there are very few using Blynk and making predictions at the same time. A few recent and representative works are quoted to demonstrate the intensity and depth of research conducted in this field.

Mora et al. [8] proposed an IoT-based framework for monitoring human vital signs. A case study was performed to monitor the pulse rates of football players during a game. The proposed system could monitor the player's vital signs and predict not only the worst-case scenario (sudden death), but also potential injuries. Manes et al. [9] proposed a distributed monitoring system for leakage detection and gas levels in hazardous environments. The sensor data were collected using a wireless sensor network. The data from the environmental sensors were sent to a remote server and presented to the director through a user interface (UI). Where critical events were detected, the proposed system was successful in tracking the environment and triggering an alert. Xu et al. [10] proposed "IoT in Industries – A Survey." Their work refers to the use of personal computing devices (cell phones, laptops, tablets, and so on) and portable web access for various IoT applications, such



Figure 1: Basic block diagram.

as medical care, food and supply chain management, transportation, mining activity, and firefighting. In our article, we have expanded the use of IoT for industrial automation. Wang et al. [11] proposed IoT and Cloud Computing in Automation of Assembly Modelling Systems. Their work illustrates how IoT can be used in several ways. They also state that different sensors can collect real-time data, which can then be exchanged for decision-making. This proposed methodology discusses how to collect real-time data by tracking devices and sending SMS/Email alerts. Shinde et al. [12] proposed an Industrial Process Monitoring using IoT. In their system, small-scale industrial applications such as energy monitoring and liquid level control can be monitored remotely using wireless devices, mobile phones, and Personal Computers (PCs). The main goal of our study is to summarize the importance of IoT in small-scale industrial applications.

IV. Proposed methodology

In this proposed work, Arduino Mega 2560 (Arduino) is used, because it has more memory than Universal Network Objects (UNO). The Arduino Mega is a micro-controller based on the ATmega2560 microcontroller

(Microchip Technology Inc). The Arduino is connected with a sensor that collects data. The collected data are sent to the IoT platform (Blynk app) through Wi-Fi module. The data are then visualized using Python, such that it is accessible and easy to understand. In a situation where the parameters reach beyond the set constraints, an alert is sent to the authorized personnel through email. Our proposed framework will monitor the humidity using DHT11, and the temperature and pressure using BME280. Since advanced manufacturing plants/factories use fossil fuels or other gases as a source of energy, in this framework the MQ2 gas sensor is used to detect gases such as carbon monoxide, LPG, and smoke. It additionally has a PIR motion sensor that detects people and movement. The major part of analyzing the information will take place on the server side. Blynk is the server in this case. The server is in charge of facilitating the web page and dealing with data entry. Predictive analysis is done using Python and regression algorithms. Regression algorithms are a subset of machine learning algorithms that belong to the Supervised Machine Learning (SVM) family. One of the most appealing aspects of supervised learning algorithms is that they simulate conditions and relations between the target output and input features to predict the value of new information.

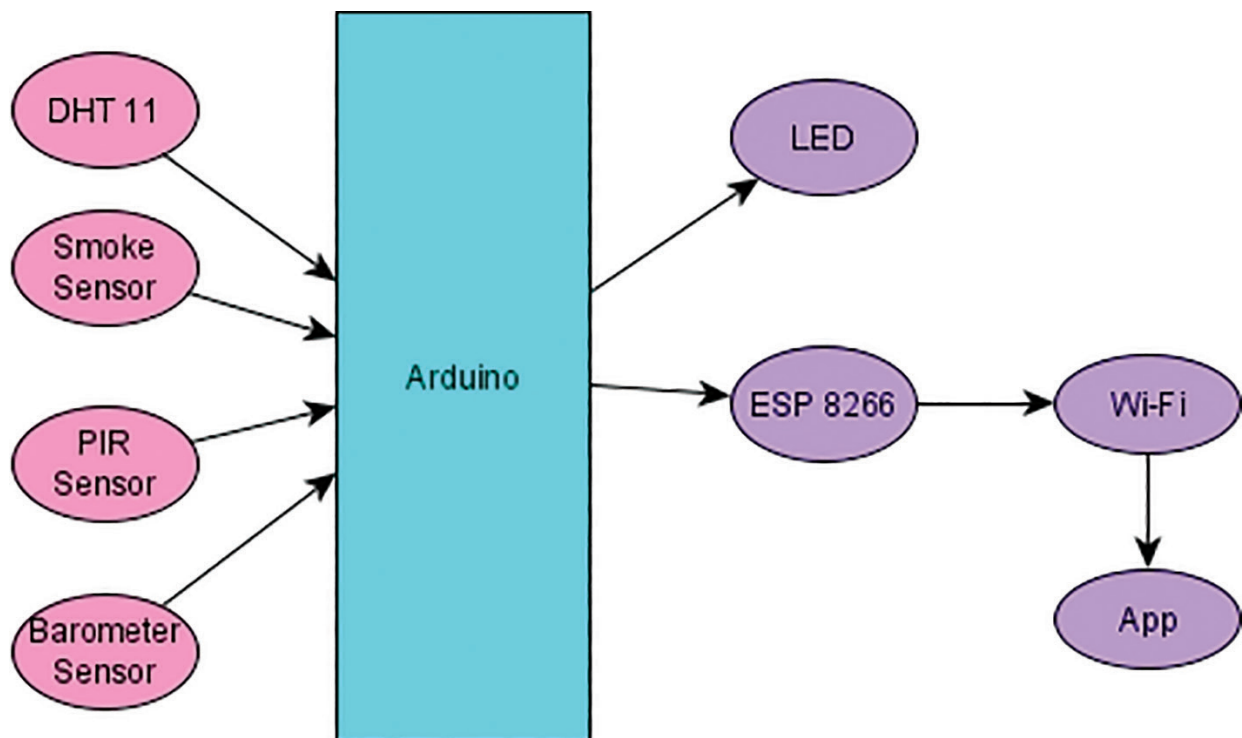


Figure 2: Block diagram of framework.

Regression algorithms predict output values based on input attributes from the data given into the system. The framework of the proposed methodology is shown in Figure 2.

V. Technical specification

The proposed methodology comprises different types of sensors and devices for data collection, which are DHT11, BME280, PIR Sensor, Smoke Sensor (MQ2), Wi-Fi module (ESP8266), and Arduino Mega. DHT11

is used for sensing temperature and humidity. The sensor can measure temperature from 0°C to 50°C and humidity from 20% to 90% with an accuracy of 1°C and 1%. The BME280 module is used for measuring the temperature, barometric pressure, and humidity. One can also estimate the altitude, because pressure varies with altitude. The sensor calculates relative humidity from 0% to 100% with a $\pm 3\%$ accuracy, barometric pressure from 300 hPa to 1100 hPa with a ± 1 hPa absolute accuracy, and temperature from -40°C to 85°C with a $\pm 1.0^{\circ}\text{C}$ accuracy. PIR

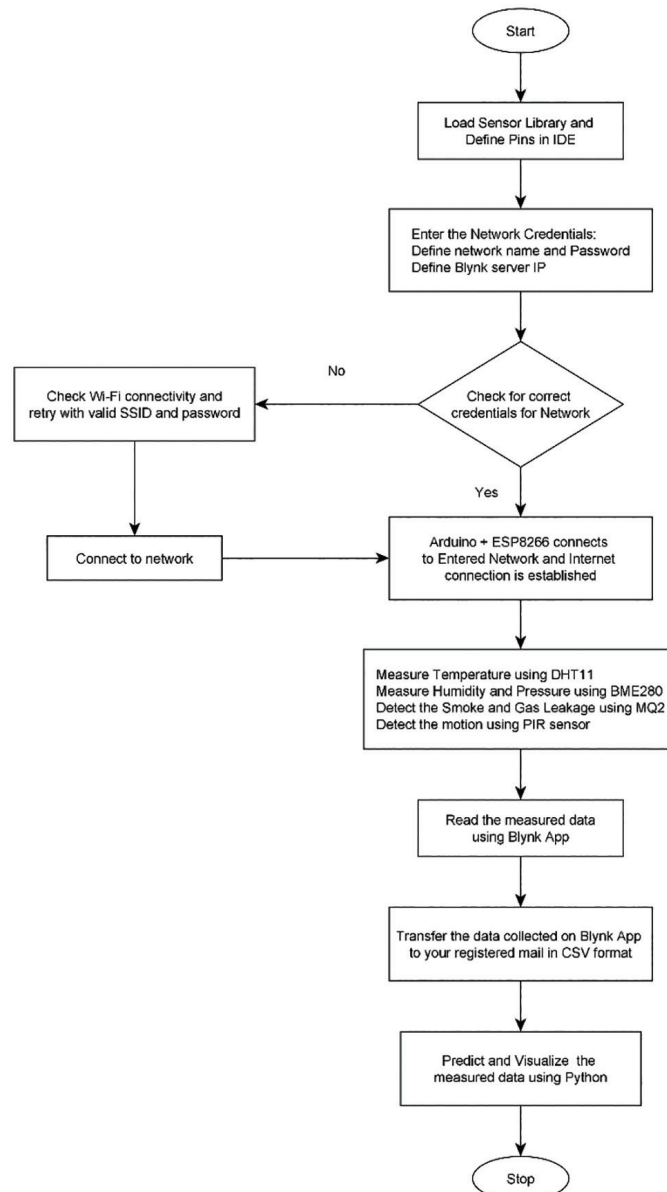


Figure 3: Flowchart for Software to process.

sensor is an electronic sensor which is also known as a motion sensor or a motion sensing sensor. This sensor has two output states: high and low; if motion is detected by the sensor, then the output is high, else it is low. The smoke sensor used is MQ2, measuring or detecting gasses such as Carbon Monoxide (CO), Liquefied Petroleum Gas (LPG), hydrogen, propane, and even methane. The smoke sensor consists of a detecting component, basically aluminum-oxide-based ceramic, coated with tin oxide and placed within a stainless-steel mesh. The Wi-Fi module used is ESP8266, which is a chip integrated with HT40 transmitter and receiver, also known as trans-receiver. It has the capability to communicate using Internet

over Wi-Fi connection and also create a network by connecting several devices for transmitting the data collected from these devices. The ESP8266 may either host an application or offload all Wi-Fi networking activities to another processor. The Transmission Control Protocol (TCP)/IP protocol is used by the ESP8266 Wi-Fi. Arduino mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be utilized as Pulse Width Modulation (PWM) outputs), 16 analog inputs, 4 Universal Asynchronous Receiver-Transmitters (UARTs) (hardware serial ports), a 16 MHz crystal oscillator, a USB link, a power jack, an In-Circuit Serial Programming (ICSP) header, and a reset button.

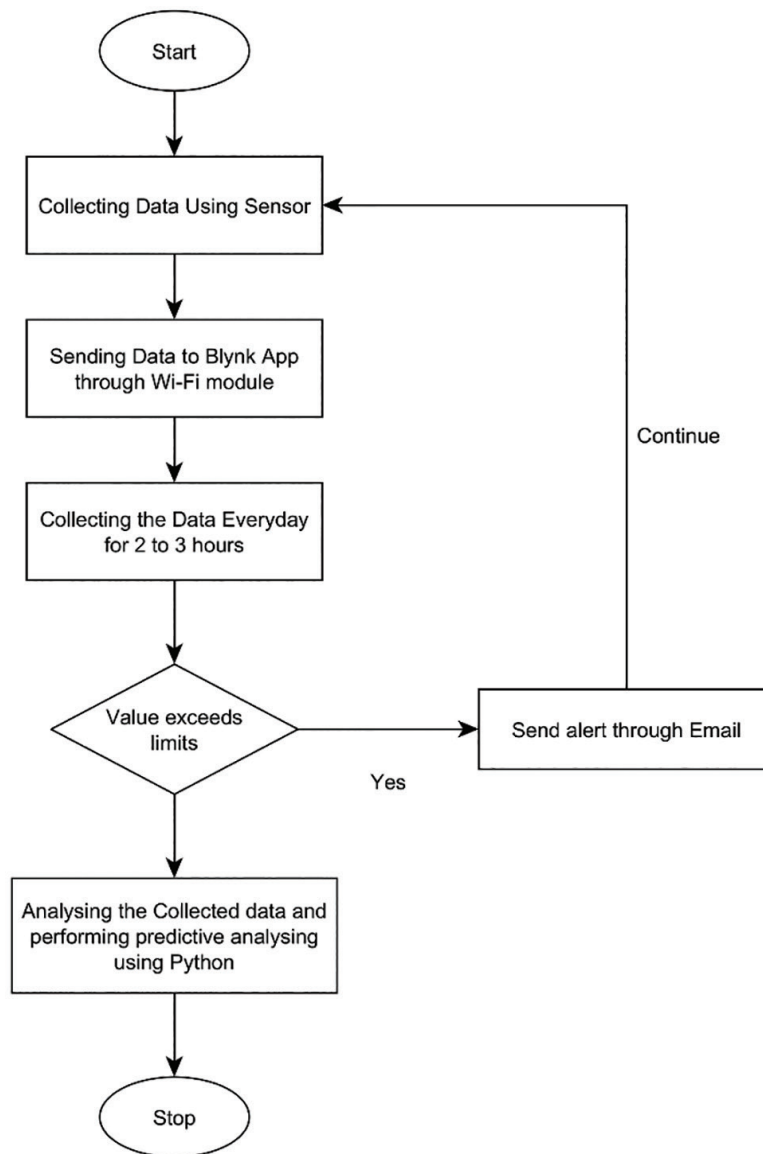


Figure 4: Flowchart for hardware process.

a. Design approach and details

The process of coding is shown in the flowchart in Figure 3. Coding is divided into three parts: the first part is for calibrating the MQ2 to obtain the R_o (value of air quality in clean air) value, which needs to be placed in the second part of coding (main body of code), as it is for the whole working process; the third part is for analysis of results obtained from Arduino. The required library is included and the variables are declared; the Wi-Fi module is connected to the Internet (set band rate 9600), and connection is established between Blynk and Arduino. After successful completion of all the steps, the data are stored in the Blynk app, which can be used for prediction (regression algorithm is used for predictive analysis) and visualization.

The hardware process is shown in Figure 4. After connection and uploading of code are done, the machine will be continuously monitored and data will be stored in the Blynk app. For every parameter the limit is set; when the values exceed the limit, an alert will be sent through Email/SMS. The collected data are sent to the registered Email in Comma-Separated Values (CSV) format for visualization and prediction.

The hardware model for industry fault monitoring is shown in Figure 5. The Arduino is associated with Wi-Fi module ESP8266 to interface with Wi-Fi. The Wi-Fi module ESP8266 is utilized to interface with Wi-Fi and the server will use the MQTT protocol to communicate with it. ESP8266 is connected to the computer through a serial interface. The sensors are attached to the Arduino's digital and analog pins. Since advanced plants/industries utilize non-renewable

energy source or other gases, the framework will also monitor gases such as LPG, carbon monoxide, and smoke, utilizing MQ2 gas sensor.

b. Result and analysis

Coding is divided into three parts: the first part is for calibrating MQ2, the second part is for the whole system, and the third part is for visualization and analysis.

The calibrated value (R_o) of MQ2 in fresh air is shown in Figure 6. The calibrated value is used in the main code, that is, in second part of code to differentiate the gases while monitoring.

After successfully connecting the Internet to Arduino through Wi-Fi module, the Blynk app is opened and the output is displayed on it. The data collected on the Blynk app are real-time data.

Figure 7 is shown the app layout that we have made in Blynk. In this, all the outputs of the sensor can be obtained via email alert and live data stream.

If any of the parameters exceeds its limit value, an instant alert is sent through email, as shown in Figure 8.

After the data have been collected for some days, predictive analysis is done using Python and regression algorithms.

c. Plotting avg temp versus time of the day for different days of the week

All the graphs (Figures 9–15) that are plotted here are between average temperature (x-axis) versus minutes (y-axis) of the day for different days of the week, that is, from Monday to Sunday. The data are collected

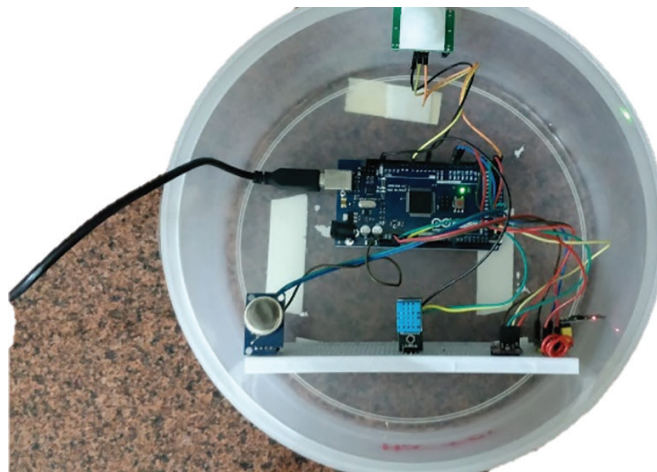


Figure 5: Hardware model.

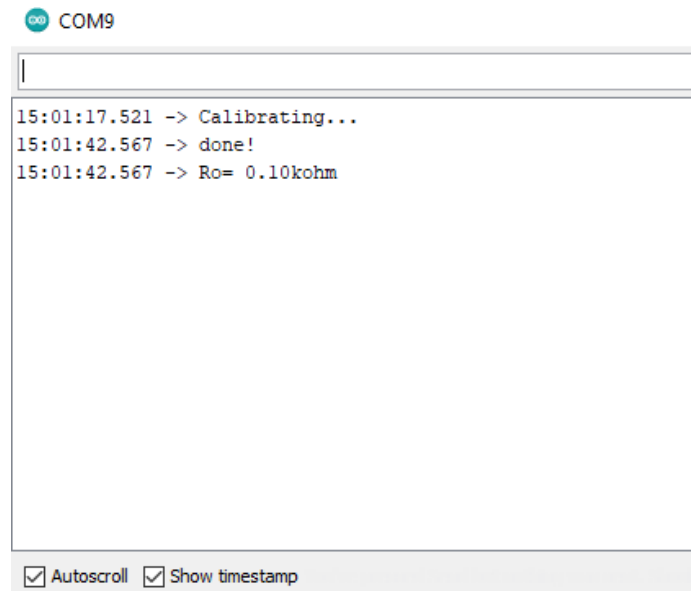


Figure 6: Calibrating MQ2.

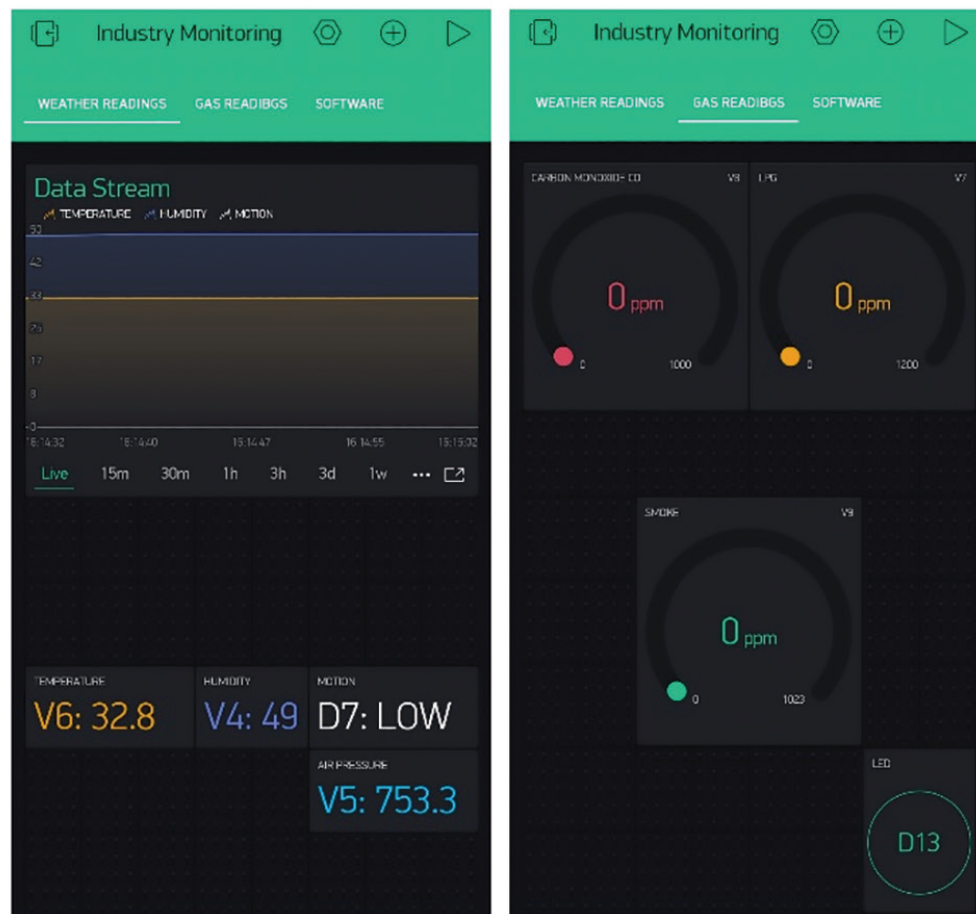


Figure 7: App layout.

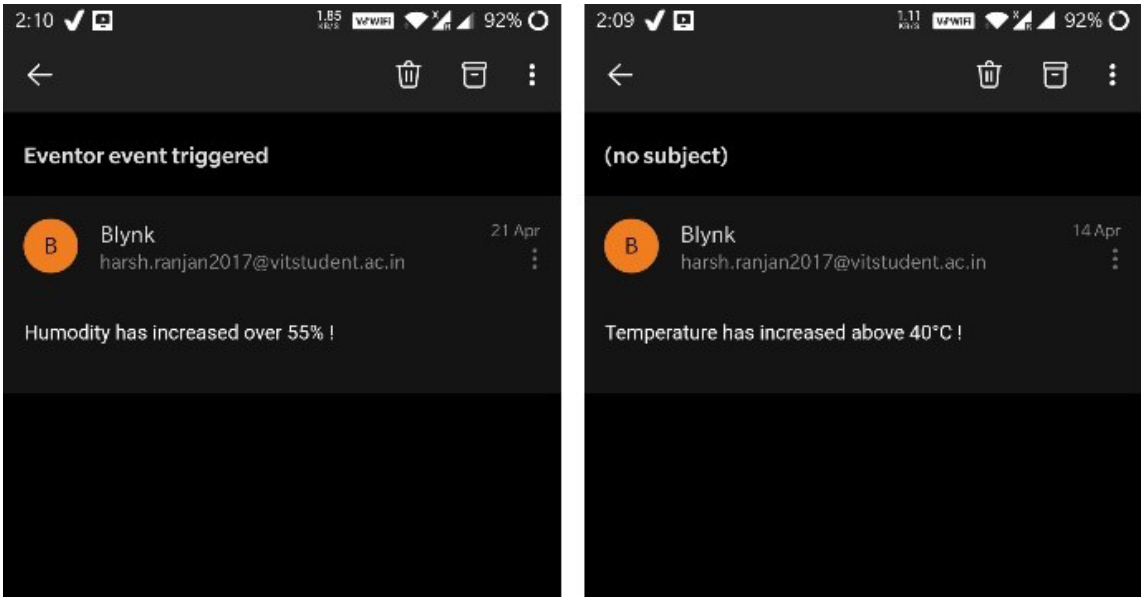


Figure 8: Email alert.

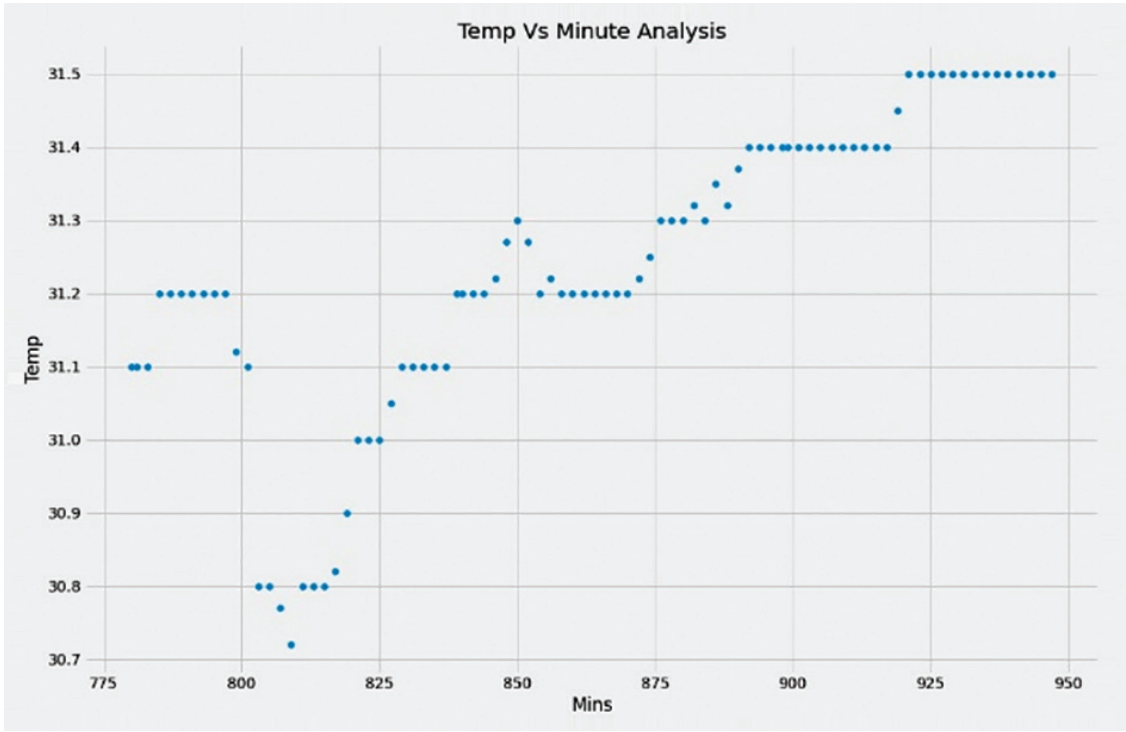


Figure 9: Avg. temp versus minutes analysis for Monday.

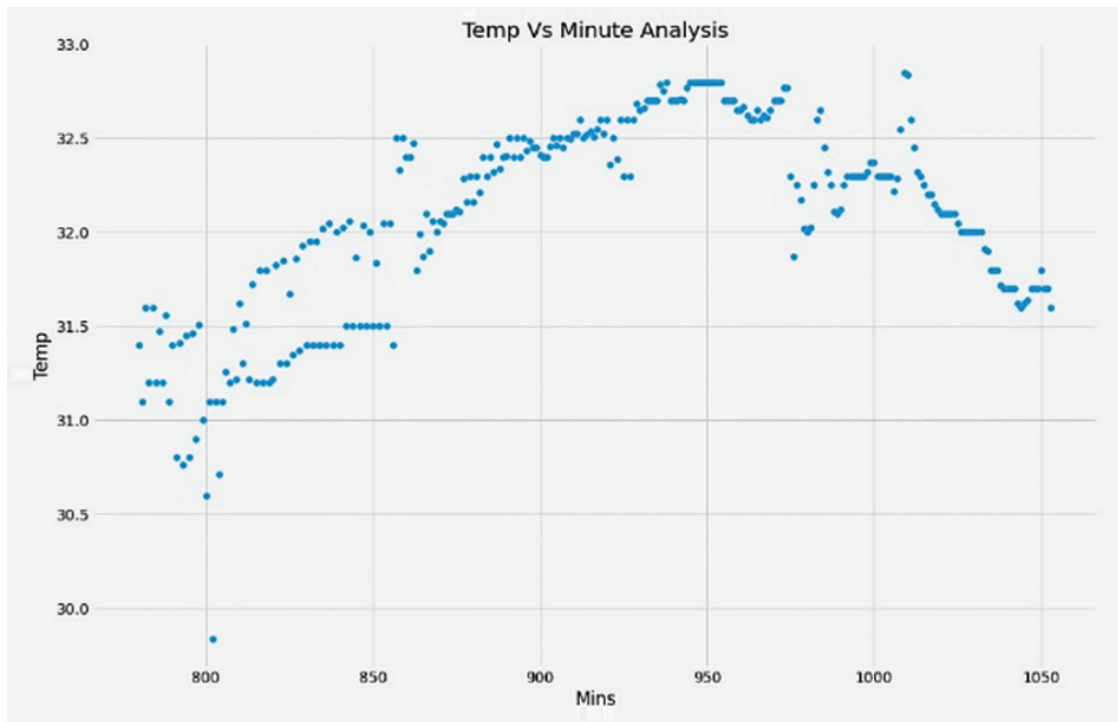


Figure 10: Avg. temp versus minutes analysis for Tuesday.

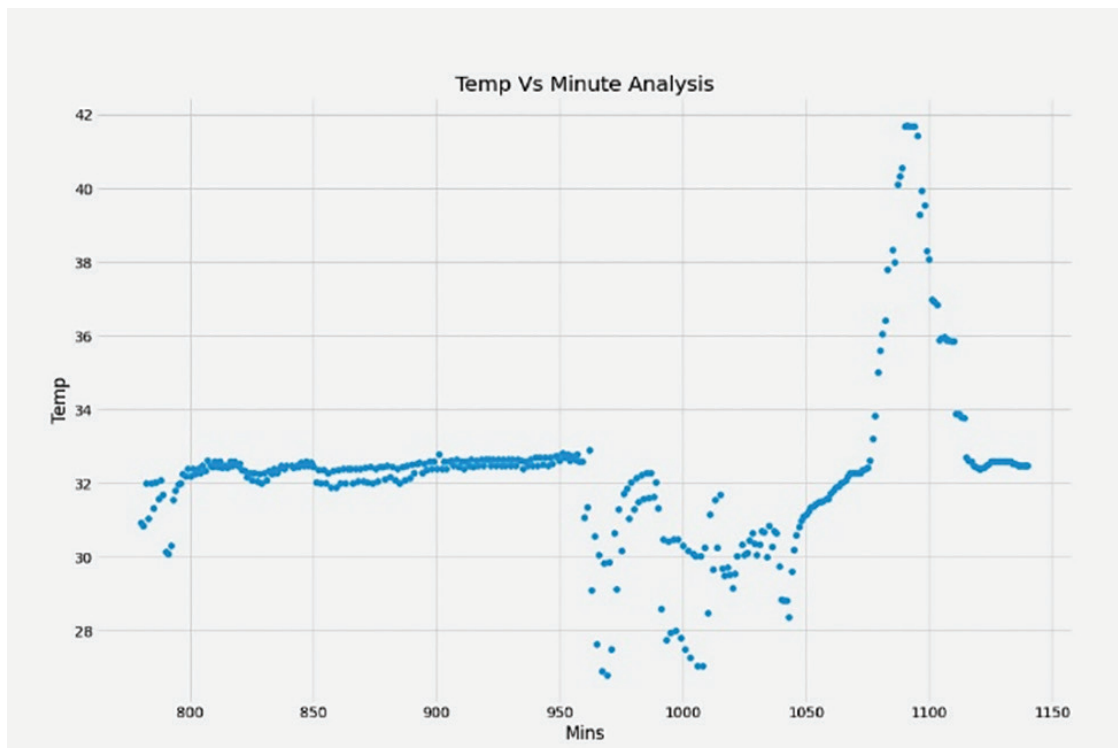


Figure 11: Avg. temp versus minutes analysis for Wednesday.

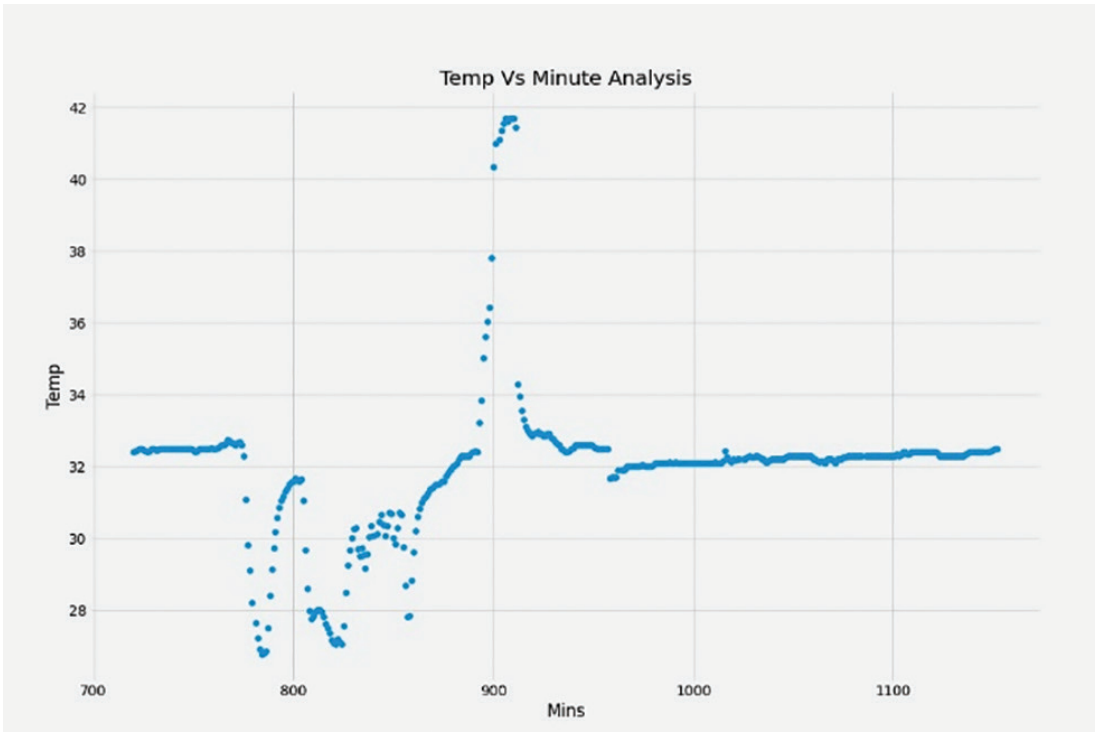


Figure 12: Avg. temp versus minutes analysis for Thursday.

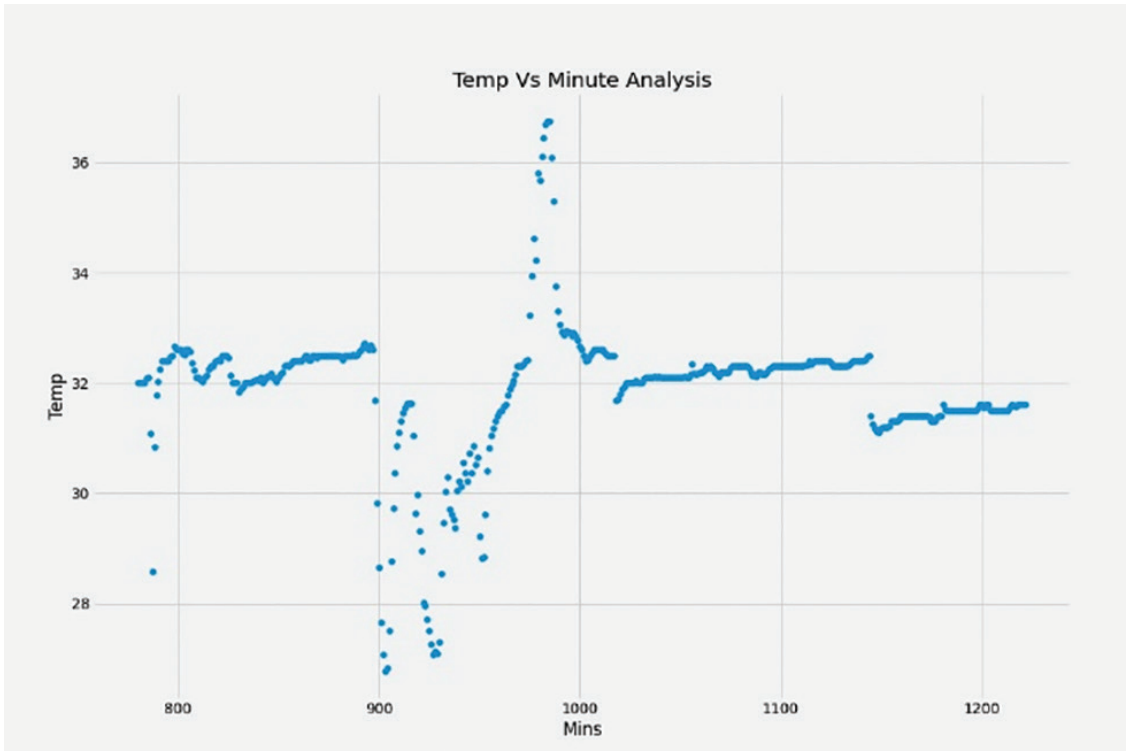


Figure 13: Avg. temp versus minutes analysis for Friday.

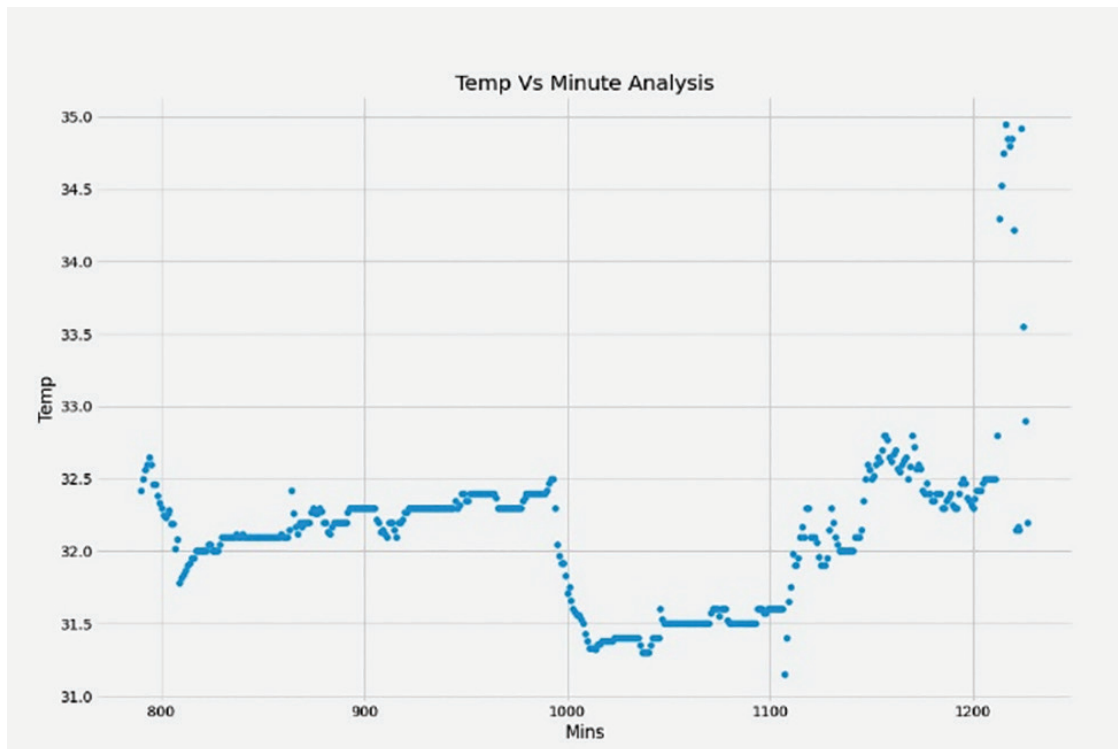


Figure 14: Avg. temp versus minutes analysis for Saturday.

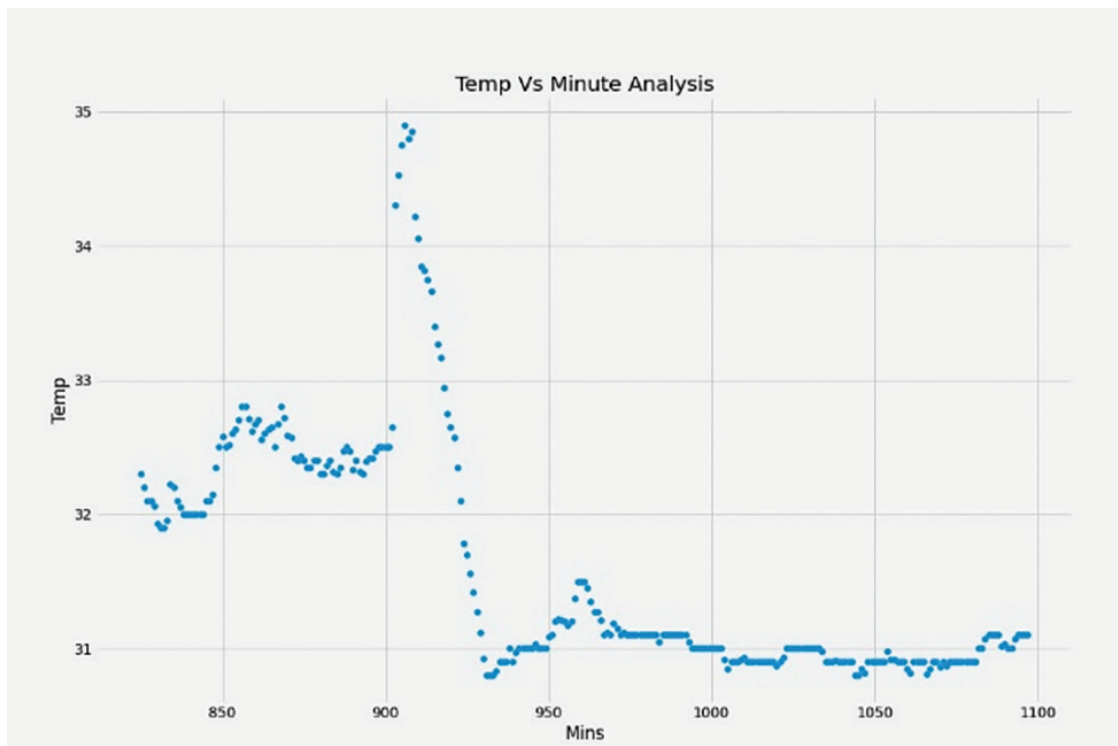


Figure 15: Avg. temp versus minutes analysis for Sunday.

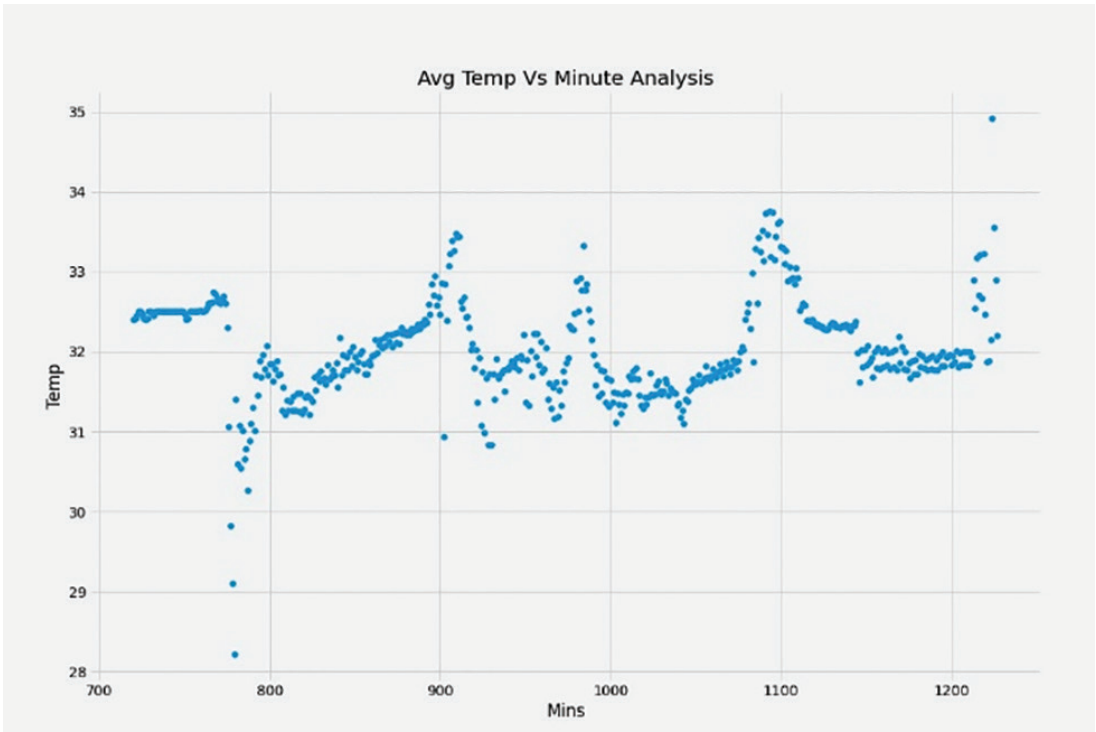


Figure 16: Avg. temp versus minutes analysis for entire data sheet.

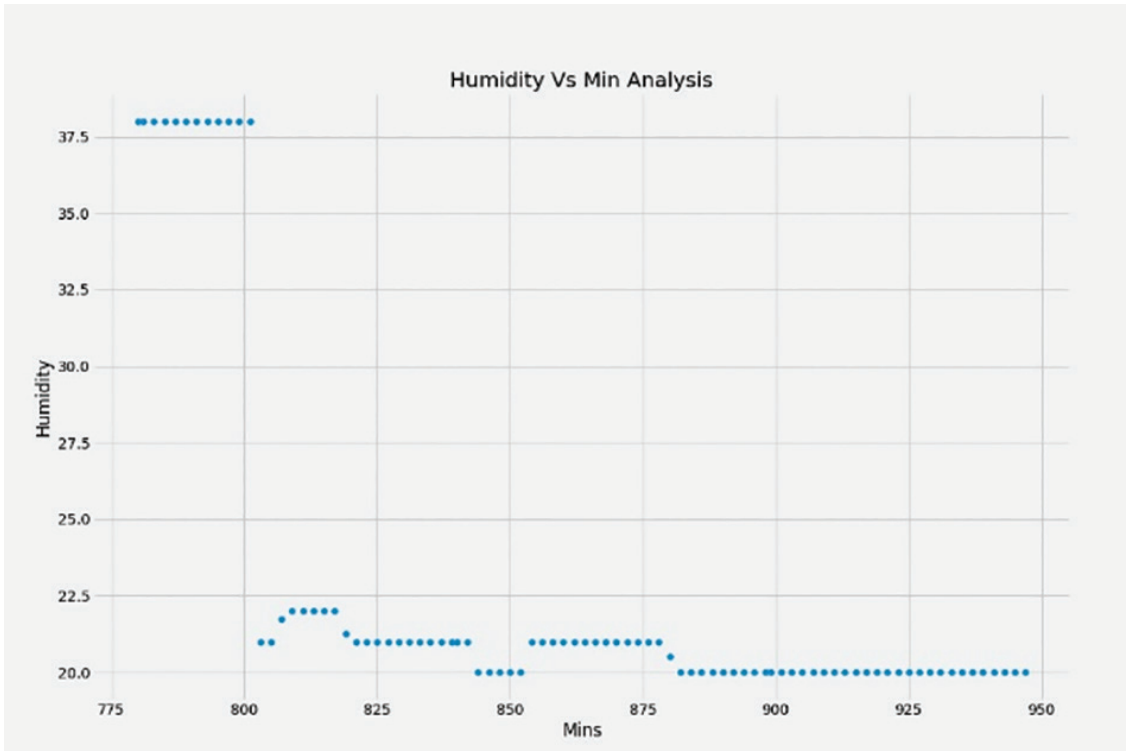


Figure 17: Avg. Humidity versus minutes analysis for Monday.

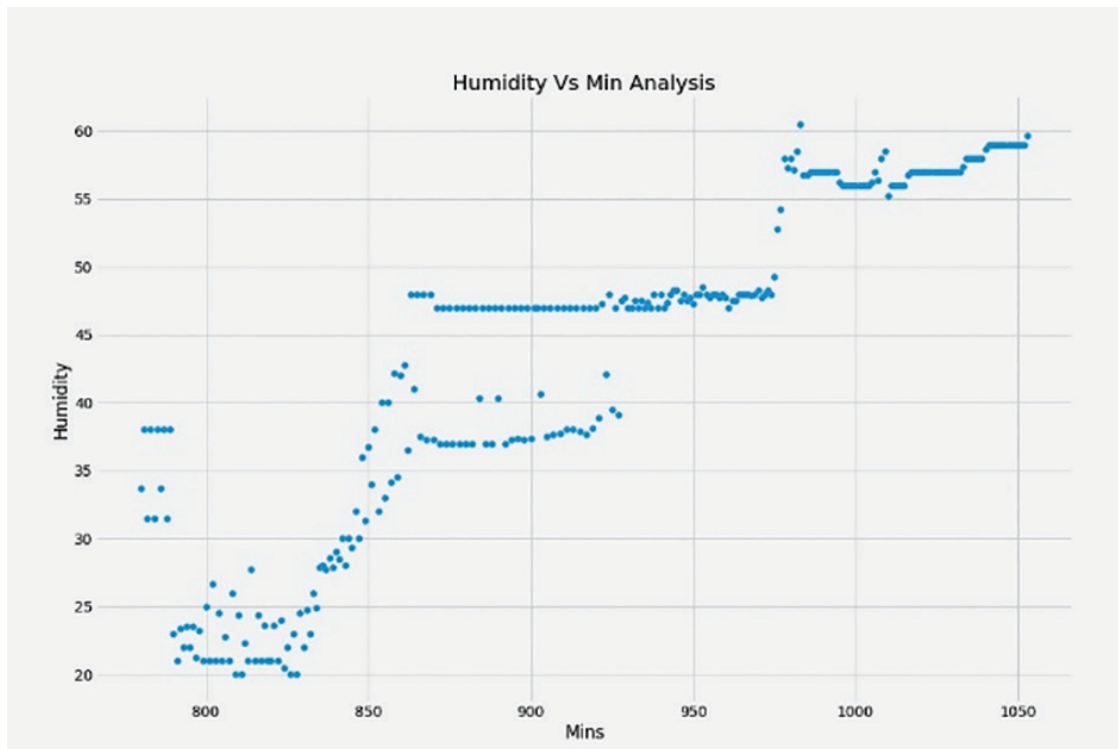


Figure 18: Avg. humidity versus minutes analysis for Tuesday.

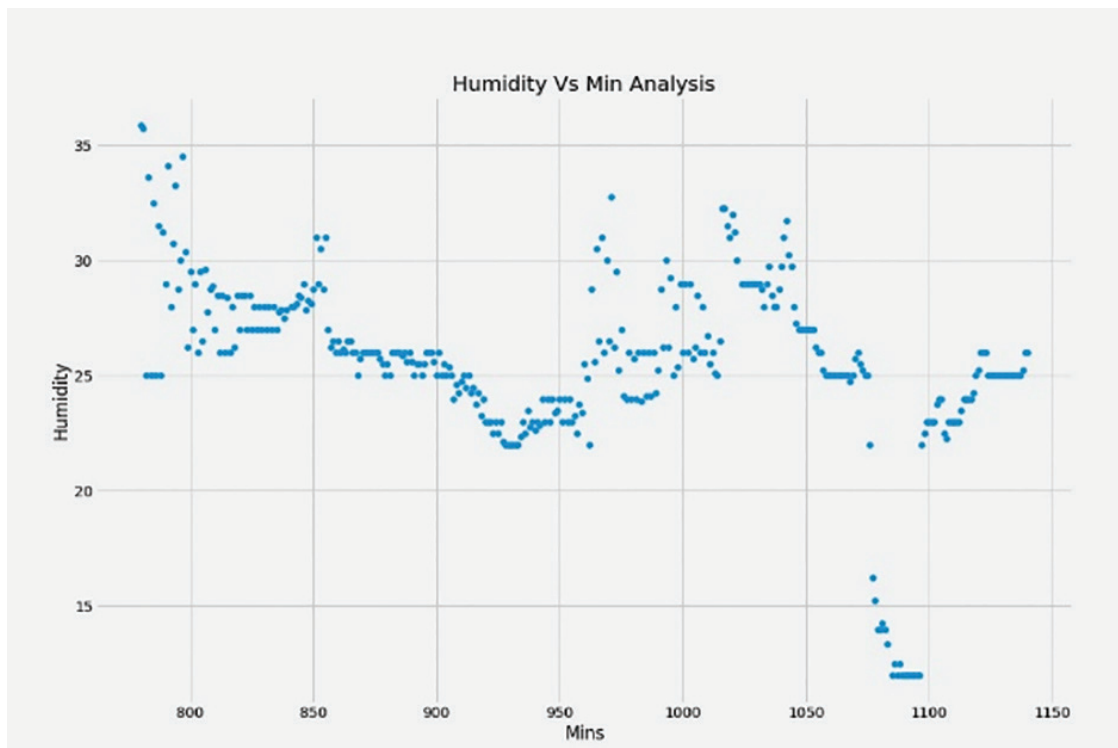


Figure 19: Avg. humidity versus minutes analysis for Wednesday.

from different sensors for 9 days (3–4 hr/day). Data are collected under different circumstance for the sake of variations. The conclusion drawn from the graphs (Figures 9–15) is that a polynomial relationship exists in each of the temperature graphs. Thus, a polynomial regression model can be built on the temperature graph.

Figure 16 is also plotted between average temp (x-axis) versus minutes (y-axis) for all the days of the week combined together; in other words, for the entire data sheet.

d. Plotting avg humidity versus time of the day for different days of the week

Figures 17–23 are all the graphs that are plotted between average humidity (x-axis) versus minutes (y-axis) of the day for different days of the week, that is, from Monday to Sunday. The data are collected from different sensors for 9 days (3–4 hr/day). Data are collected under different circumstances for the sake of variations. The conclusion drawn from the graphs in Figures 17–23 is that in the case of humidity, the graph is not able to spot any relationship between

time and the humidity value. Thus, the polynomial regression model cannot be built on the humidity graph.

e. Visualization of the polynomial regression result

A polynomial regression model is a type of regression analysis in which the correlation between the independent variable (i.e., x) and the dependent variable (i.e., y) is demonstrated as an n th degree polynomial in x [13]. The polynomial models can be utilized in those circumstances where the connection between the explanatory and study variables is curvilinear. Polynomials can also be used to model a nonlinear relationship in a restricted range of explanatory variables. The graphs are plotted between temperature versus minutes for the prediction for each day of week. In these graphs (Figures 24–30), the red dots are the real values and the blue curve are the predicted values. Polynomial regression models are typically fit utilizing the method of least squares. From Figures 24–30, a polynomial model is obtained that can be used to predict temperature values for a given

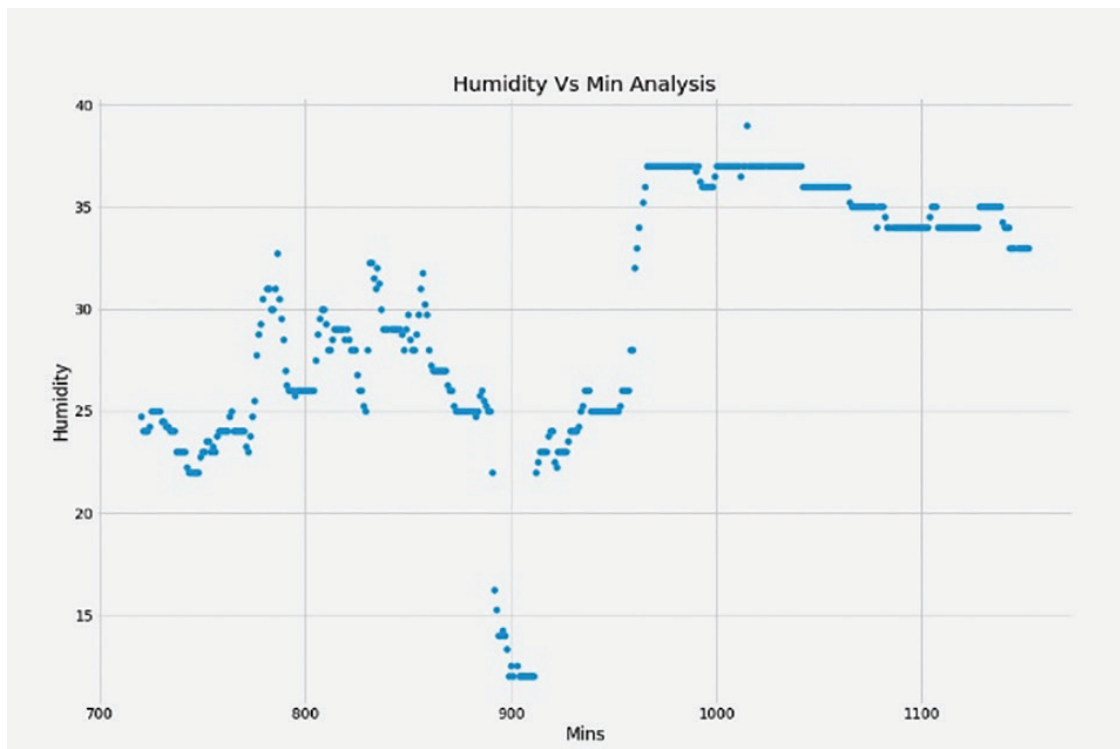


Figure 20: Avg. humidity versus minutes analysis for Thursday.

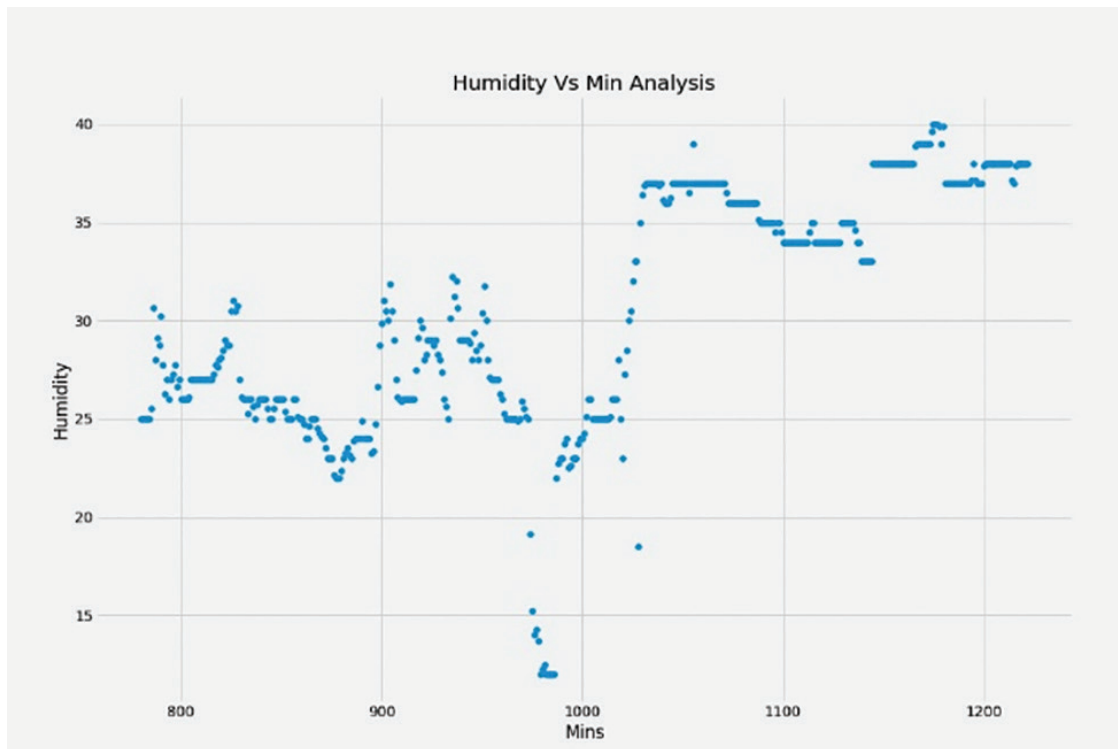


Figure 21: Avg. humidity versus minutes analysis for Friday.

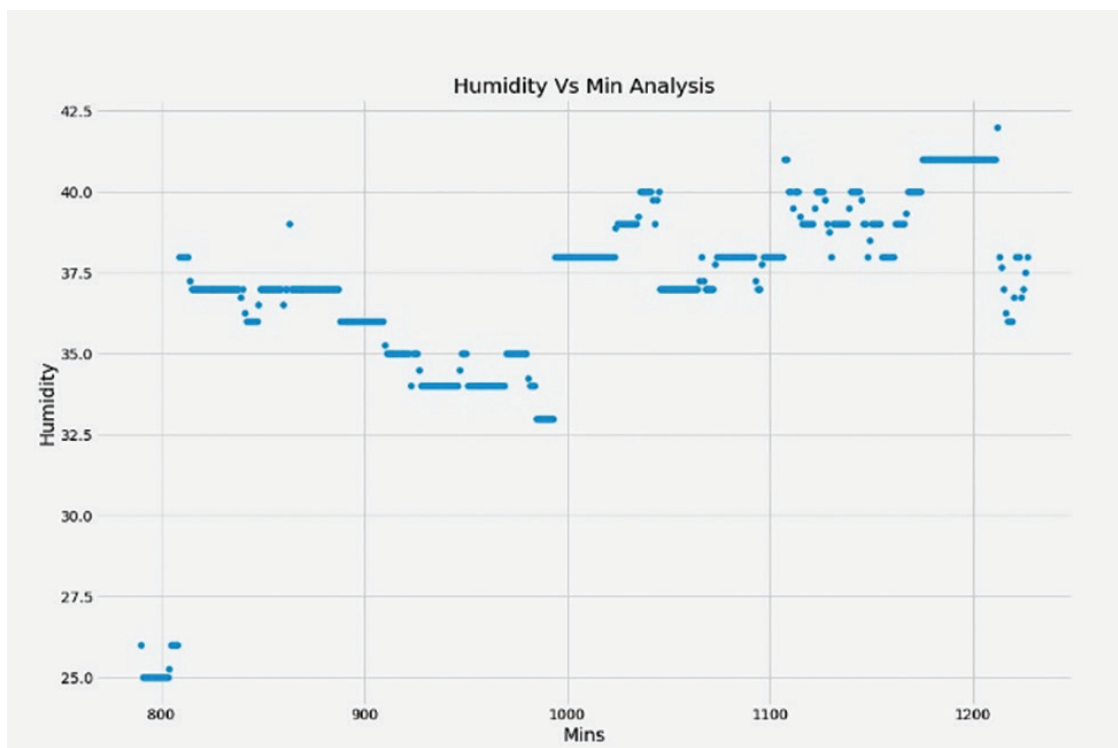


Figure 22: Avg. humidity versus minutes analysis for Saturday.

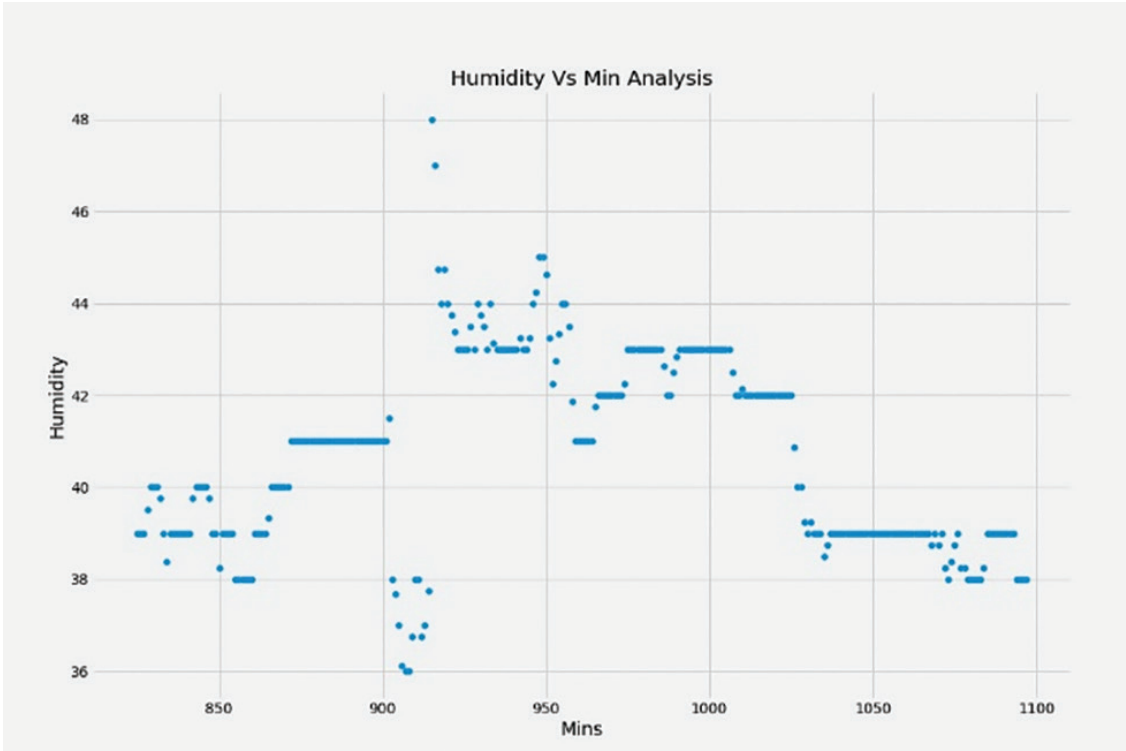


Figure 23: Avg. humidity versus minutes analysis for Sunday.

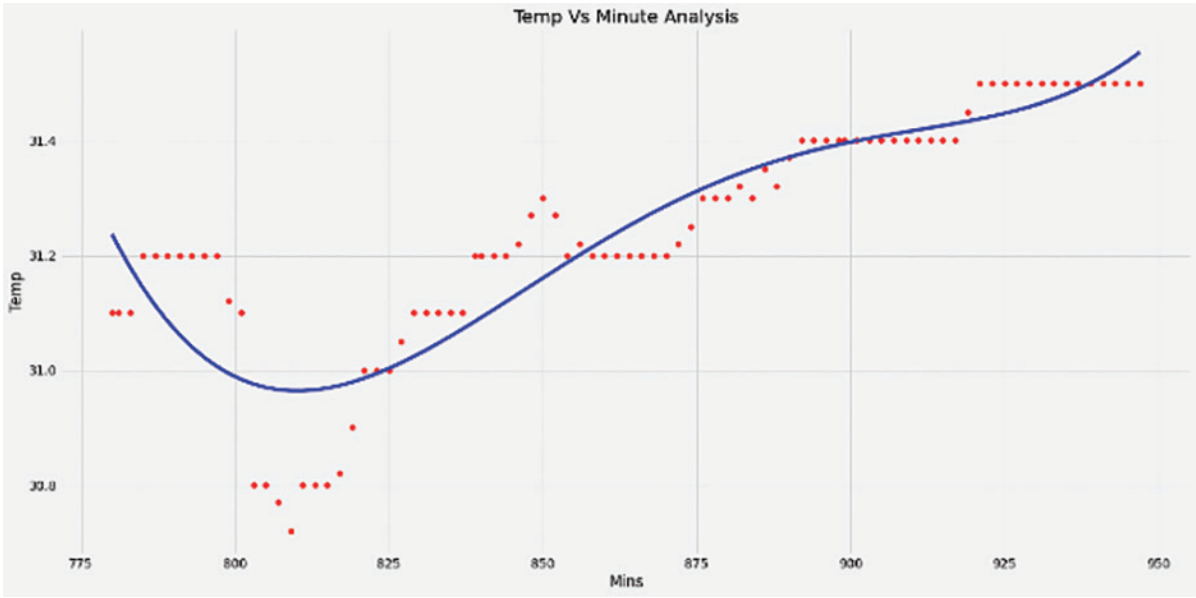


Figure 24: Visualization of regression result on Monday.

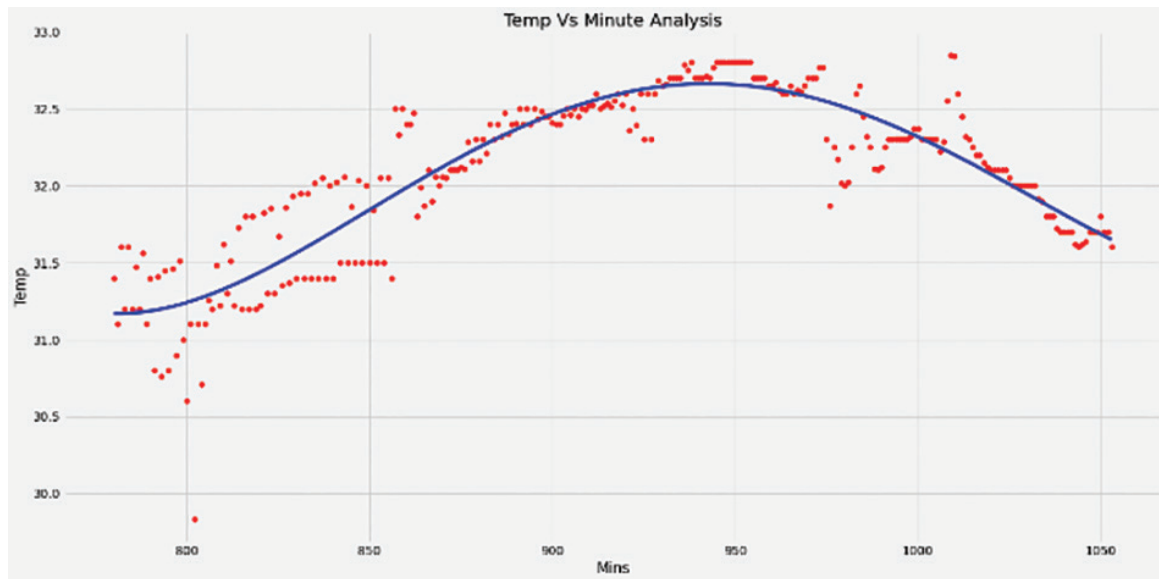


Figure 25: Visualization of regression result on Tuesday.

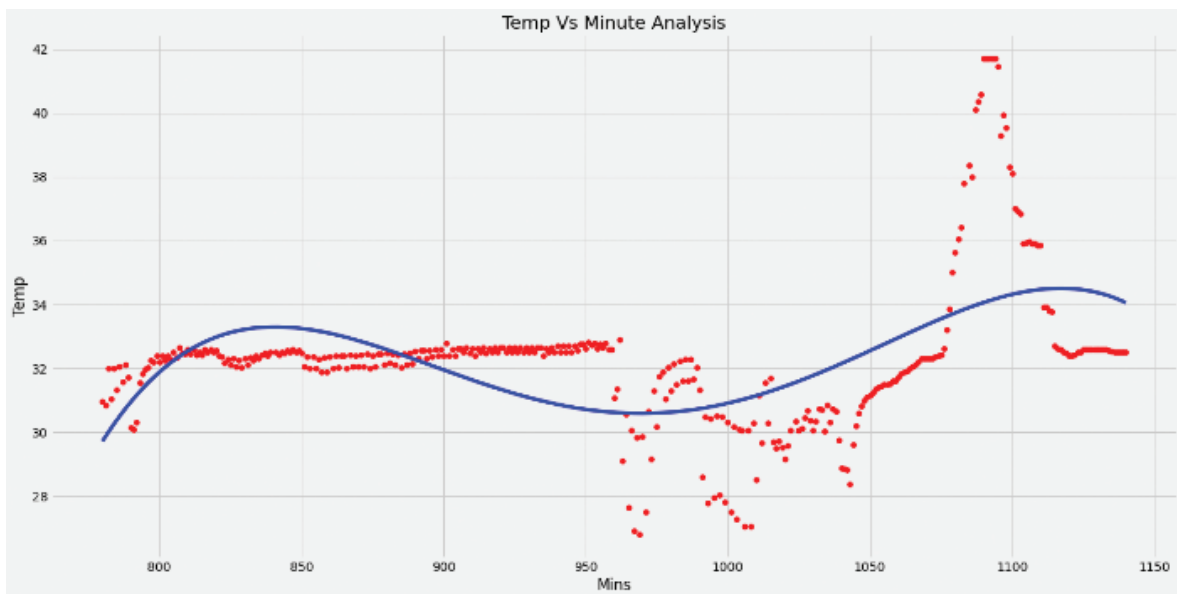


Figure 26: Visualization of regression result on Wednesday.

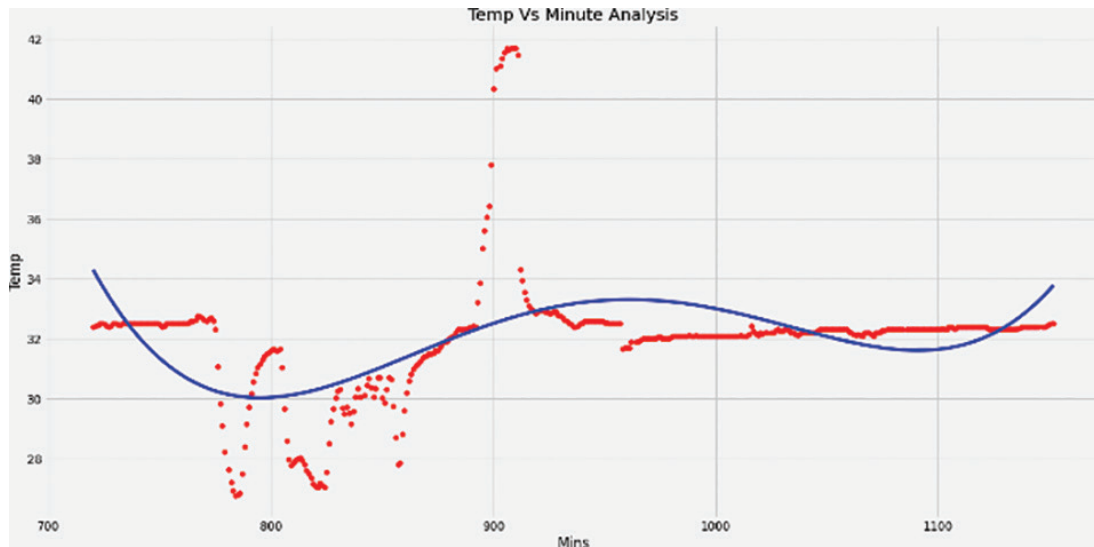


Figure 27: Visualization of regression result on Thursday.

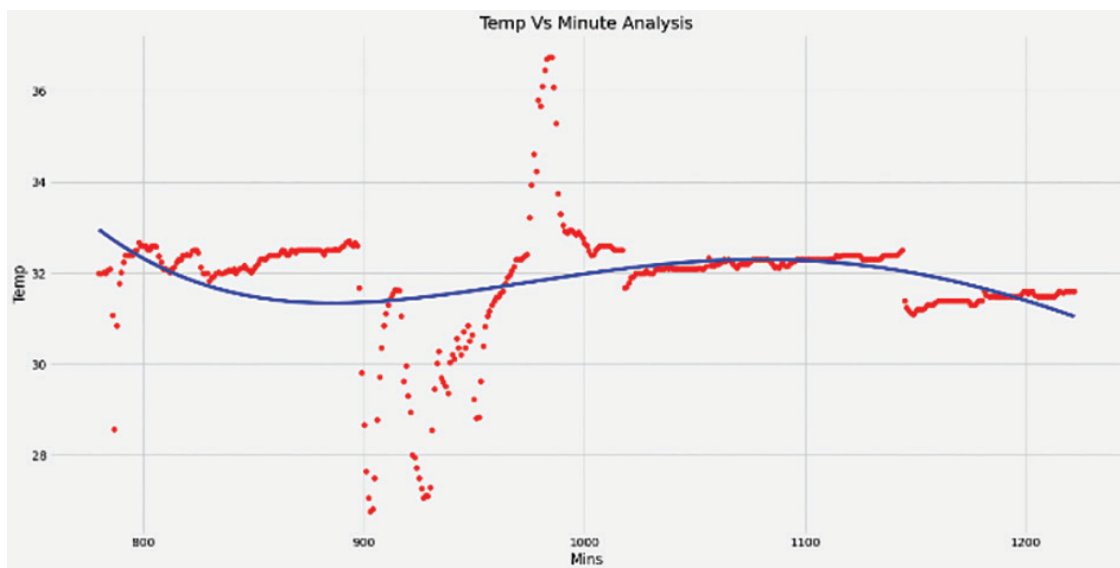


Figure 28: Visualization of regression result on Friday.

time on a given date, and it can be used for future predictions. However, in the case of humidity, it is not able to spot any particular relationship between the time of day and the humidity value.

VI Conclusion

Automation is now enabling industrial sectors because of the widespread availability of the Internet, which we can access from anywhere in the world. By using IoT, industrial outcomes are developing and setting

threshold values for each sensor through ESP8266. If the values of these sensors are not within a specified range, it may pose a danger to anyone working in the vicinity, as well as being a considerable risk of machine damage. Here, we have included different sensors for different alerts, so that authorities can take the appropriate decisions and actions in the event of a fault in the industrial environment. The goal of the study is to advance industrial development by linking a network of sensors and increasing industry performance.

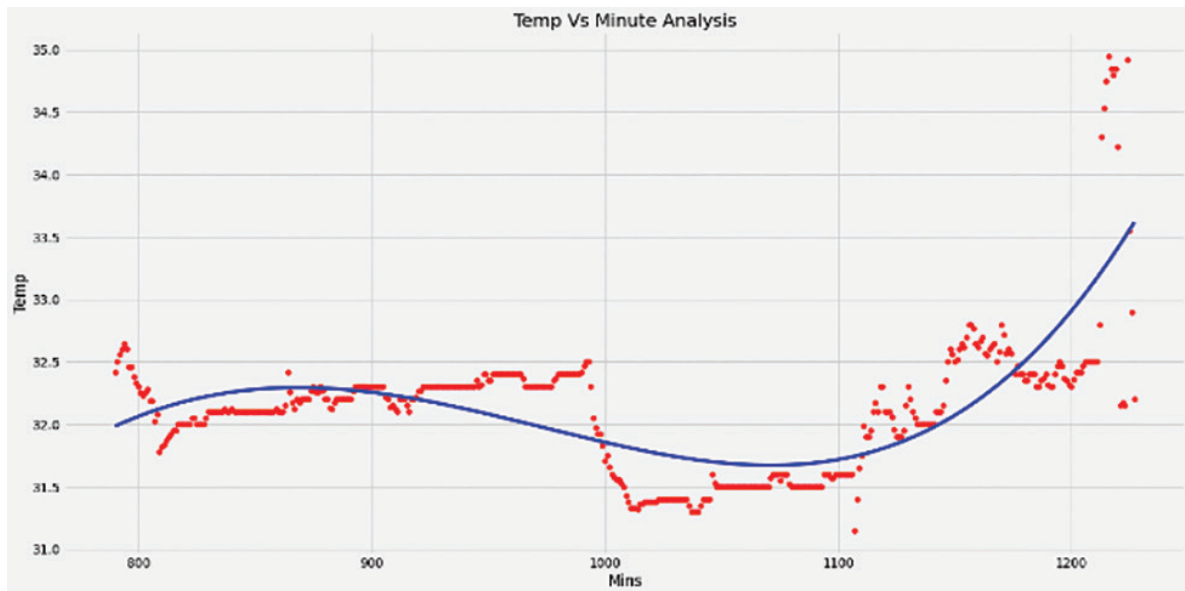


Figure 29: Visualization of regression result on Saturday.

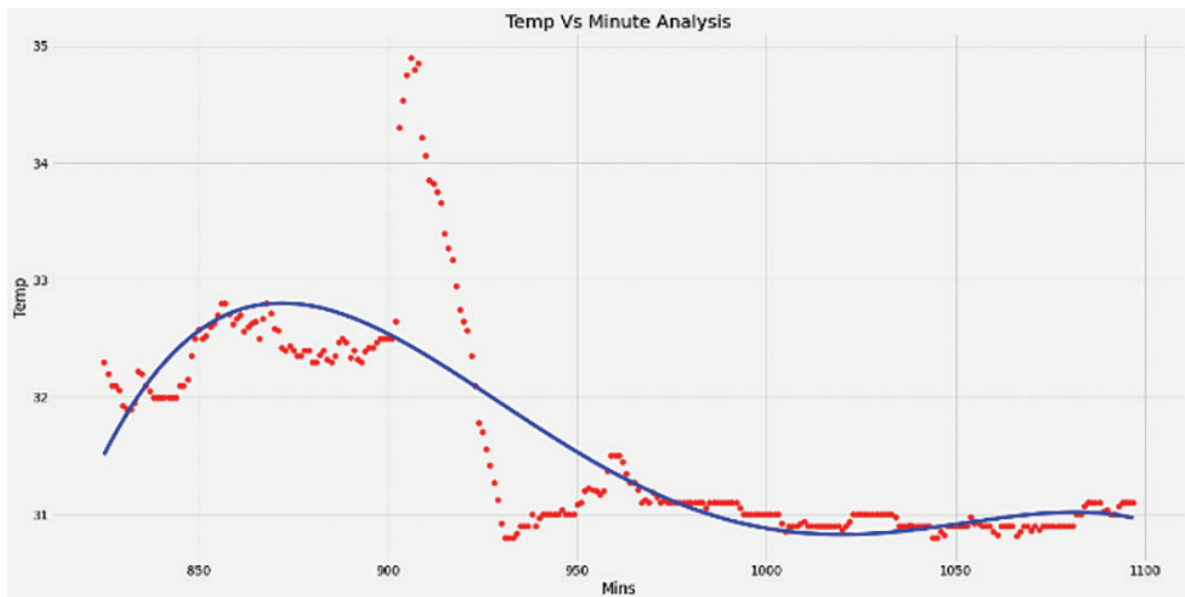


Figure 30: Visualization of regression result on Sunday.

The system is easy to understand, simple, as well as power efficient. All the hardware implemented for this proposed work and the outputs were achieved and verified successfully. A lot more can be achieved if this proposed idea is applied to the real world. The setup can also be upgraded to track the health of any employee in the plant by using a future wearable device in the wellbeing coat to measure their blood pressure and pulse rate. It can also be used to make more accurate and powerful industry grade equipment. It also includes a camera to show the image of the fault occurring machine.

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