IoT Based Smart Fruit Warehouse Management System

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Abstract

We are living in a world of technology and automation that is impacting every domain possible, scalability, productivity, increasing efficiency, and at the same time cutting down efforts and investments. The Internet of Things has given us the power of connecting everyday objects to the internet, and hence they can be controlled and monitored from anywhere in the world. Traditional warehouses, unfortunately, still rely on human practices like checking the thermometer and humidity meter manually, analyzing special it, and then deciding for regulation of parameters inside the warehouse. The majority of this product is damaged due to a lack of proper warehousing mechanisms and is declared unfit for consumption; humans are toiling their way through the day, managing and monitoring all the environmental conditions of the warehouses are the general Picture of warehouses around the globe today, and that comes with a cost of human errors resulting in wastes of resources and decreasing efficiency. A lack of a warehousing mechanism causes a massive loss of food, money, and resources. An automated warehouse will eliminate human error, and it will make the storage more efficient and organized, thus resulting in a lesser probability of producing wastage. However, it cannot be compatible with every environment controller available in the market, and the degrading level changes from fruit to fruit, yet the proposed solution can solve 80% of the problems faced by traditional warehouses. The micro-controller receives respective values from each of the sensors and sends them to the server. The server stores the data and produces the data to the mobile application for better visualization of data. The micro-controller regulates the parameter controlling unit by the server's response, which also includes the change of parameters requested by the user. This solution does a multiparameter monitoring and control system to check the quality of the fruits. As a result, we get to operate and monitor the warehouse from anywhere using a mobile application.

1. Introduction

Agriculture is the backbone of our country, and it plays a vital role in our country's economy. Nearly 70% of our country's population primarily depends on agriculture for their livelihood. India is the second-largest producer of fruits and vegetables globally and accounts for 11% of the world's produce. About 30-40% of fruits and vegetables are annually estimated to be a waste due to lack of proper storage facilities, and they are declared to be unfit for consumption. Environmental factors play an essential element in determining the quality of the fruits. These ecological factors are mainly temperature and humidity.

Fruits and vegetables are living biological bodies; they also have a respiratory system that continues during their life and even after harvest. By respiration, fruits and vegetables take in oxygen and give out carbon dioxide. Hence, there should be proper storage facilities to avoid wastage.

Existing methods of monitoring smart fruit warehouses still depend on humans for checking temperature and humidity manually, analyzing the data, and taking precautions for regulating the parameters inside the warehouse. As humans are prone

to error, manual warehouse control increases the chances of damage to the fruits. Therefore, we require an automated warehouse system to monitor the environmental conditions. This automated warehouse system helps monitor the environmental conditions and analyze the data, take actions, and regulate the parameters based on the result.

Applying the Internet of things technology in the warehouse can monitor the temperature and humidity etc. Real-time and monitor the whole process Intelligently to improve efficiency. The system is based on the concept of thing networking and uses different sensors, wireless communication technology, and the Internet to form a remote monitoring intelligent system for the warehouse. The remote monitoring system based on this networking technology can have real-time monitoring of the temperature and humidity, alcohol level information which makes the whole monitoring process centralized.

Contributions

- A user-rich interface android application is made to monitor and control the warehouse globally.
- Cloud based data storage for cross-platform access as well as remote access of the data
- Machine learning algorithms are used to make a predictive analysis of the warehouse to make it profitable.
- Load cells and relay modules are being added to monitor the stock of fruits and control the warehouse.

2. Objectives

- To reduce food losses and increase food safety using the internet of things.
- To monitor the variation in the limit set for the sensors and send real-time data to the warehouse owner.
- To design and develop an android application for real-time monitoring of the warehouse.
- Visualization of data depending on price, quantity, and customers visited. Predicting the price and selling quantity on a particular day and foresee profit or loss by comparing the expected value from the yearly average and total average of the specific day in the year.

3. Proposed Methodology

The proposed solution is split into two modules: the hardware module and the software module.

The hardware module senses the data and provides the input, and the software module has two parts:-

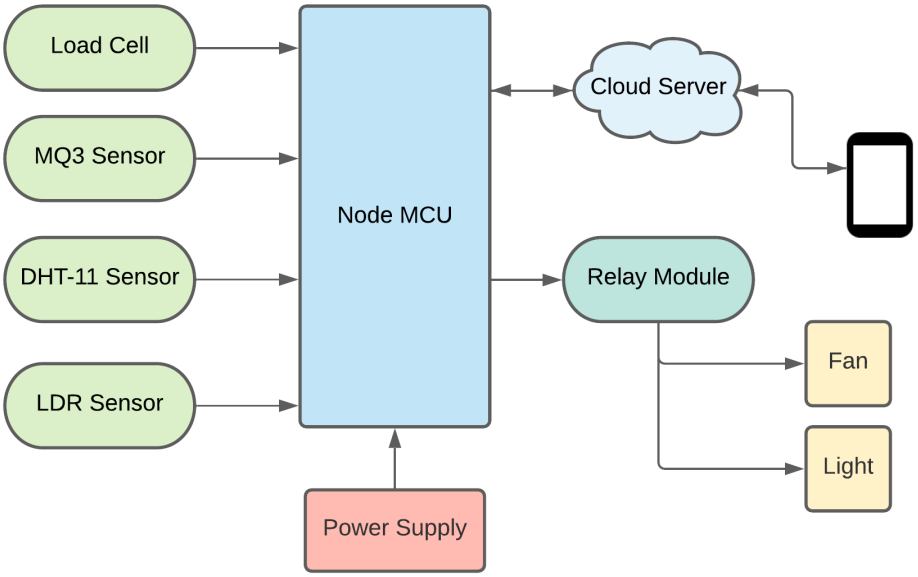
➔ It works on the input and provides automation and control.
➔ Use of machine learning to predict the price and the selling quantity.

Hardware Module

The hardware module consists of sensors, a microcontroller. Sensors used are LDR, DHT-11, MQ-3, and Load Cell. Node MCU is used as a microcontroller that has an inbuilt wifi module. Apart from these relay modules are used to control the appliances.

- **Node MCU:** NodeMCU is an open-source Lua-based firmware and development board specially targeted for IoT-based applications. It has an inbuilt wifi module. So it can be used as both a microcontroller and wifi module. Its operating voltage is 3.3V, the input voltage is 7-12V. It has 17 GPIO pins, of which one pin is analog, and the other is digital. Furthermore, it has a clock speed of 80MHz, input voltage 7-12V.
- **DHT-11:** The DHT11 is an essential, ultra low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air and spits out a digital signal on the data pin (no analog input pins needed). It is relatively simple to use but requires careful timing to grab data. We can get new data from it once every 2 seconds, so when using the library from Adafruit, sensor readings can be up to 2 seconds old.
- **LDR Sensor:** It is a light-sensitive device used to indicate the presence or absence of light or to measure the light intensity. In the dark, their resistance is very high when the LDR sensor is exposed to light. The resistance drops dramatically, depending on the light intensity. LDRs have a sensitivity that varies with the wavelength of the light applied and are nonlinear devices.
- **MQ3 Sensor:** It is used for sensing alcohol concentration. Moreover, the sensing is based on the change of resistance of the sensing material when exposed to alcohol; by the components mentioned above, which haven't been placed in a simple voltage divider network, alcohol concentration can be detected. This sensor works on 5V DC and draws 800mW. It can detect alcohol concentration anywhere 0 to 1000ppm
- **Load Cell:** It consists of a load cell and HX711 module. A load cell is a force transducer. It converts a force such as tension, compression, pressure, or torque into an electrical signal that can be measured and standardized. As the force applied to the load cell increases, the electrical signal changes proportionally. HX711 module is a load cell amplifier breakout board for the HX711 IC that allows easy-read load cells to measure weight.
- **Relay Module:** The relay is the device that opens or closes the contacts to cause the operation of the other electric control. It detects the undesirable

condition with an assigned area and gives the commands to the circuit breaker to disconnect the affected area through ON or OFF.



Fig(1) Node diagram of the proposed Smart Warehouse Management system

Software Module:

Android Application: An android application is a software application meant to run on a device with an android operating system. Our system provides an android application built using java. In this application, we can monitor and control the warehouse, predict prices and the selling quantity.

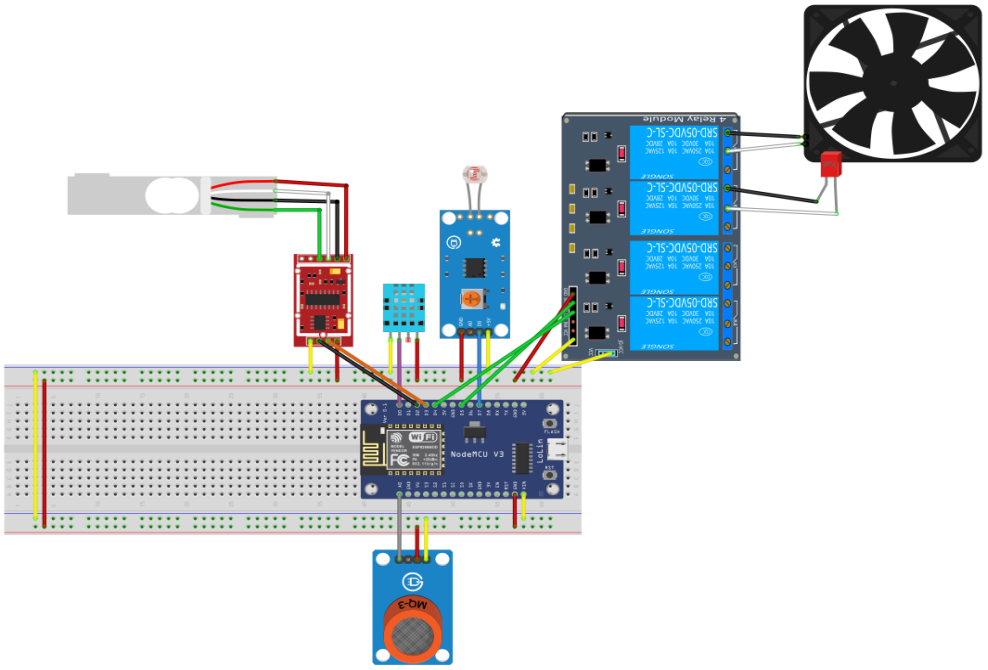
- **Prediction of price and selling quantity:**

  Multiple variate linear regression is a statistical technique that uses several explanatory variables to predict the outcome of a response variable. Multiple linear regression aims to model the relationship between explanatory (independent) and response (dependent) variables. This function allows us to make predictions about one variable based on the known information about another variable. Linear regression can only be used when there are two continuous variables—independent and dependent variables. The independent variable is the parameter that is used to calculate the dependent variable. In this project, we have sample data of 1yr consisting of the quantity sold, customers visited, and the price of 1kg of fruits each day. We can use this data to make a statistical analysis and predict the visitors, the cost of the fruits to be sold for making profits. This Machine learning technique makes the warehouse manager make predictions much easier and more probable. The

data here taken is sample data; this can be extended to the actual life data and is more suitable for the warehouse manager.

Hardware and Software Integration:

The Management system is incomplete without the integration of both hardware and software. This covers the integration of the components mentioned above with the details of connections. The circuit diagram is depicted in fig(2). The figure shows all the links to the sensors.



Fig(2) Schematic Representation of Smart Warehouse Management

Sensors are connected to the microcontroller (Node MCU), as shown in the above figure. DHT11 is connected to the digital pin of the Node MCU. It gives two readings: temperature and humidity. The temperature reading is in degrees Celsius (°C), and moisture is given in percentage(%). LDR is connected to the digital pin of the Node MCU. The reading of this sensor is binary; it has only two states either ON or OFF(detects whether the light is on or off).MQ3 sensor is connected to the analog pin of the Node MCU. It is a value of the alcohol level between 0 to 1000. The load cell is connected to the digital pin of the microcontroller. It gives the data of the weight in grams.

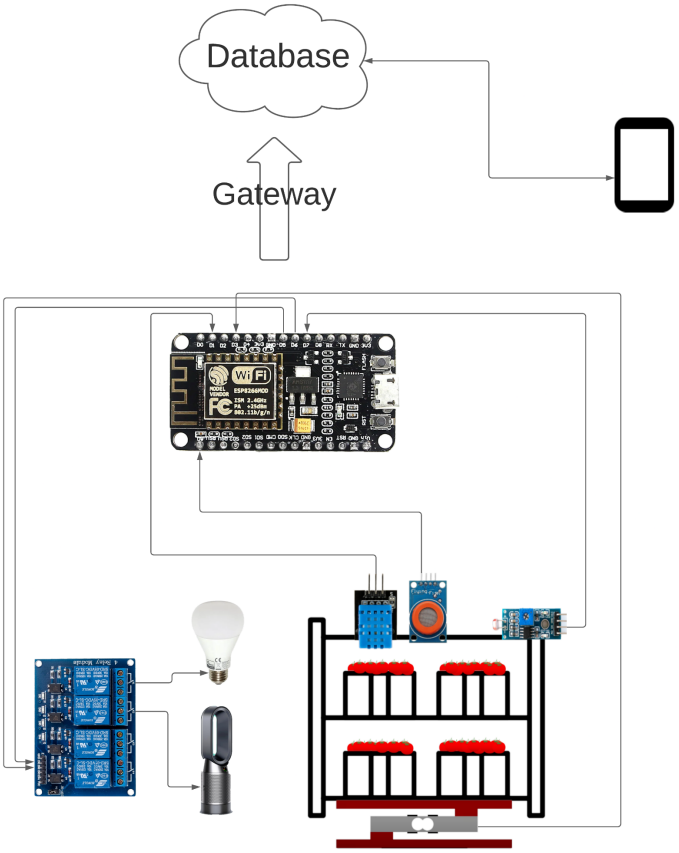
The data collected from the sensors is sent to the Node MCU. Node MCU collects the data and processes it. Then the data is sent to google firebase. Two parameters are essential to communicate with firebase. They are FIREBASE_HOST and FIREBASE_AUTH. This enables the data exchange between Node MCU and

firebase. Then we require the wifi SSID and password; after this, Node MCU will connect to the network and communicate with the google firewall. After that Node MCU connects to the wifi network. Once the network is connected, the serial monitor will display the connection status and print the IP address. If the host address and authorization key are correct, Node MCU will successfully connect with the firebase server. Then we can send the data to google firebase using the path provided in the code. After uploading the code Node MCU connects with the wifi network, the serial monitor will show the reading of the sensors. When the data is displayed on the serial monitor, at the same time, the information is sent to the firebase database. To check the real-time entry of the data, open the firebase console window.

To send the data to an android application, we first design an android application, and then we will send sensor data to the android app using firebase and Node MCU. We just insert the firebase console in the code of the application. Now, we can see the data on the app screen on the smartphone.

Warehouse environment parameters can be controlled and monitored from anywhere through the android application. When the temperature is above the optimum value then we can ON the fan from the android app. Similarly, if the brightness is less than the android app's optimum value, we can turn ON the light. A relay module is used to control the devices(fans, lights, and other appliances).

The data sent to the firebase can be monitored using the android application. In the android application, we can set the starting date about when the stock has been filled, and from that day onwards, we can see how many days it is fresh. Furthermore, we can also see the history of the parameters(temperature, humidity, light, weight). Along with this, we can also predict the price of the fruit on a particular day by entering the number of customers and quantity sold. We can also predict selling quantity on a specific day by entering the price and number of customers, comparing programs execution, this quantity with the yearly average and the particular day price, and predicting loss or profit.



Fig(3) Conceptual view of proposed Smart Warehouse Management System

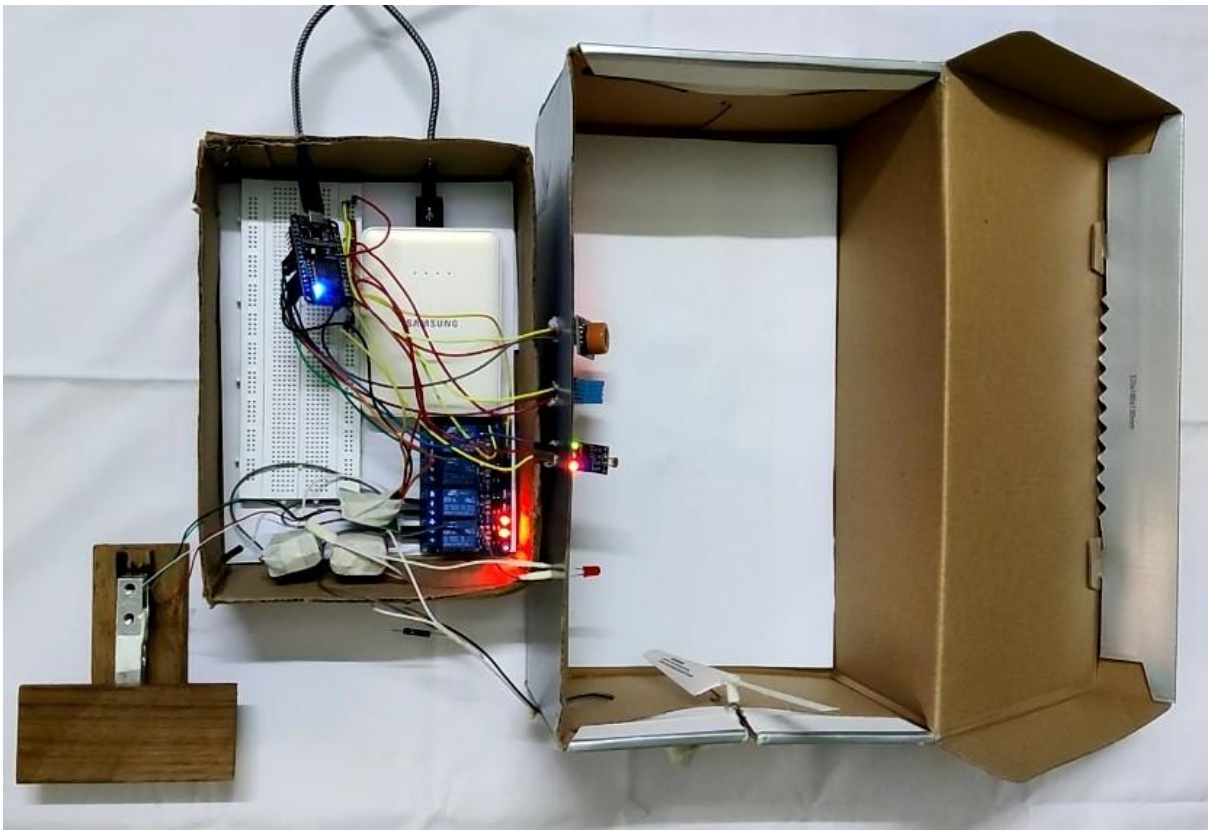
4. Results

As a result we have a fully automatic system and a framework that allows us to automatically read the climate of the warehouse and send the data to the cloud servers which could further be fetched by a client mobile application in a remote location.

This system mainly consists of 5 parts The Sensors, The microcontroller/Gateway, The Cloud Server, The Client Mobile Application and The Machine Learning Model

The Sensors, i.e DHT11, MQ3 and LDR sensors take physical inputs from the surroundings and then convert them into digital signals that are easy for the microcontroller to understand and process.
The sensors are integrated in the crate in which the fruits and vegetables are to be kept, so that humans don't have to carry around the manual sensor to get a reading of a particular crate.

These are the raw data which previously required a human to go inside the warehouse to get the data and then manually store it in a hand book which further took more human effort and time to get the data and to keep records of the data.



Fig(4) Prototype of proposed Warehouse Management System

The Microcontroller/Gateway, i.e. Node-MCU 1.0 is the SoC/main microcontroller/gateway in this system. a microcontroller basically is a cpu that controls all the physical components of the IoT system i.e. individual sensors and the wifi module that is ESP8266.

All the sensors are connected to the microcontroller and in turn it acts as the manager for the system components, the microcontroller also governs the communication between the hardware and the cloud server through the api

The microcontroller manges everything, it sequences the data reading from the sensors, and schedules the uploading of the data to the server via the gateway

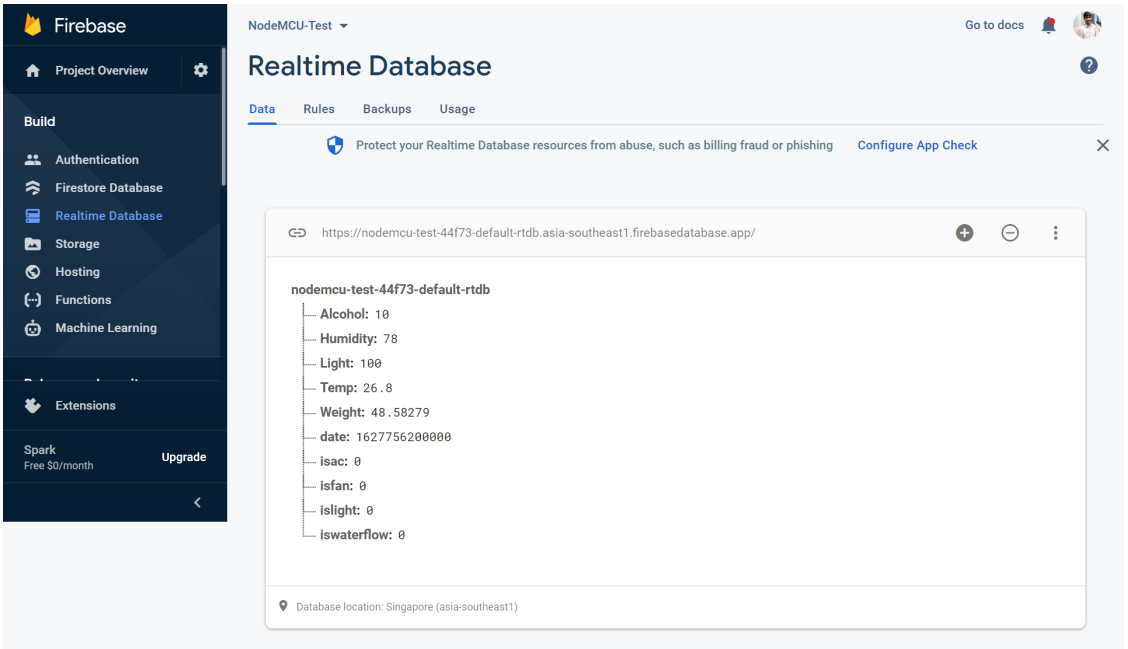
NodeMCU is the most suitable Micorcontroller for our system because it is Low cost, has Integrated support for the WIFI network and has a low energy consumption. NodeMCU is a compact soln for the iot system as there would be more than 1 crate in real life scenario.

The Cloud Server, i.e. Google Firebase. The cloud server provides an api which can be accessed by both microcontroller and the mobile application. The cloud server takes data from the microcontroller via the gateway available in the microcontroller, and then stores it in the cloud database which could further be accessed by the remote mobile application for monitoring.

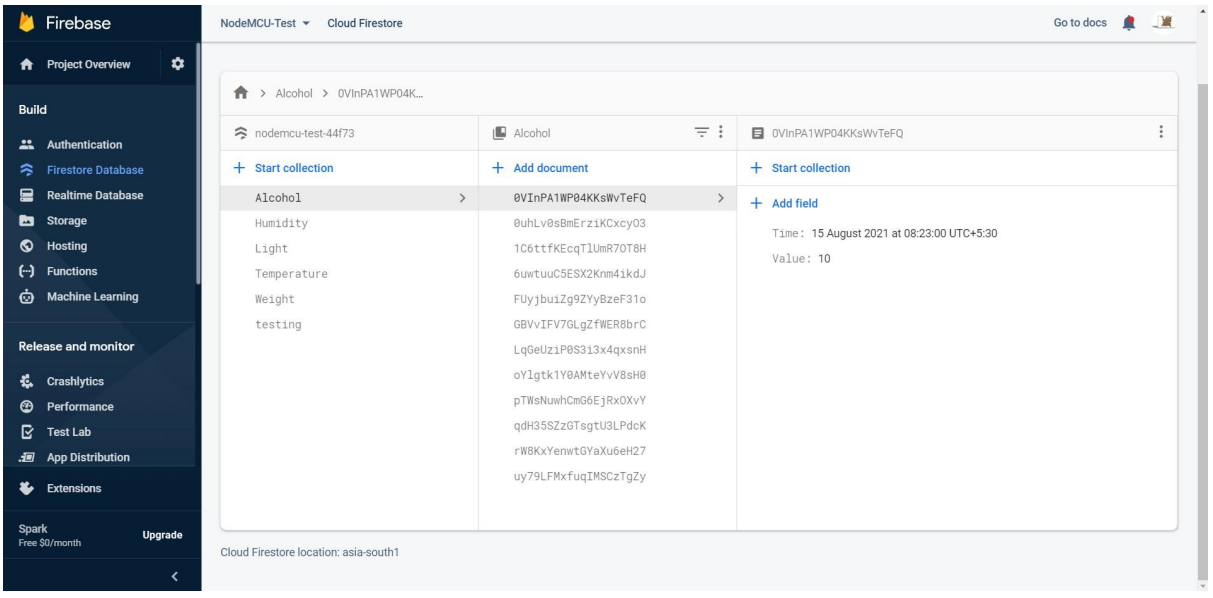
Firebase server collects the data generated by the sensors like humidity, temperature, light availability, alcohol level and the weight of the crate and for this it use mainly 2 type of databases,

first, is the realtime database for the realtime reading from the sensors

second, is the firestore database which collects the history of the previous recordings.



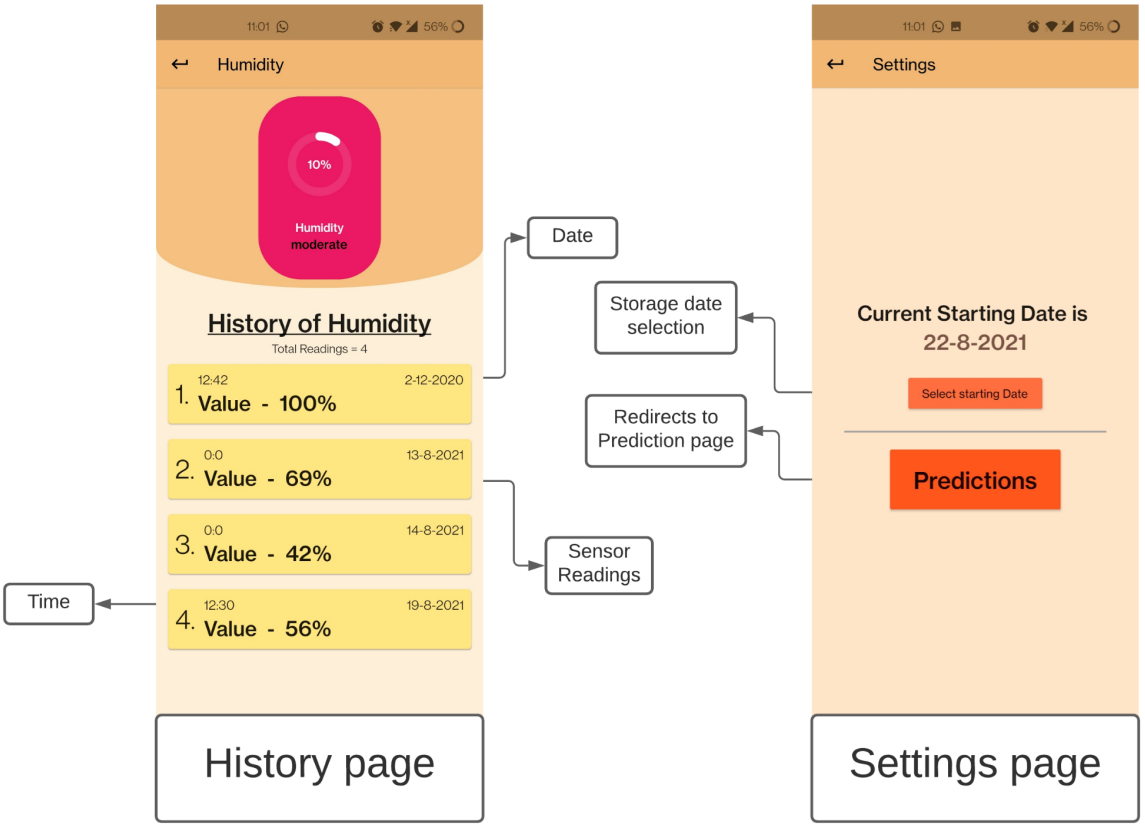
Fig(5.1)Realtime Database of proposed Smart Warehouse Management System



Fig(5.2)Firestore Database of proposed Smart Warehouse Management System

The Benefit of databases is that we can store data and it can be used in the future. It also makes the data centralized which means it can be accessed from anywhere in the world. It also provides easy access to data and in fact reduces human effort in maintaining data in registers. Another benefit is that it analyzes data for the machine learning model. It promotes a disciplined approach to data management. It improves the quality and consistency of information.

The Client Mobile Application, is the UX/UI for the user to read all the data and to control the environment controllers available in the system. The mobile application uses the same api (firebase api) of the same server as the microcontroller to access the data which was updated by the microcontroller and formats it further and presents all the data in a systematic and more human readable format.
The application is developed in android studio using flutter SDK.
The application is especially developed for a rich user interface which is easy to understand even for someone who is not familiar with much high technology, such as a farmer.

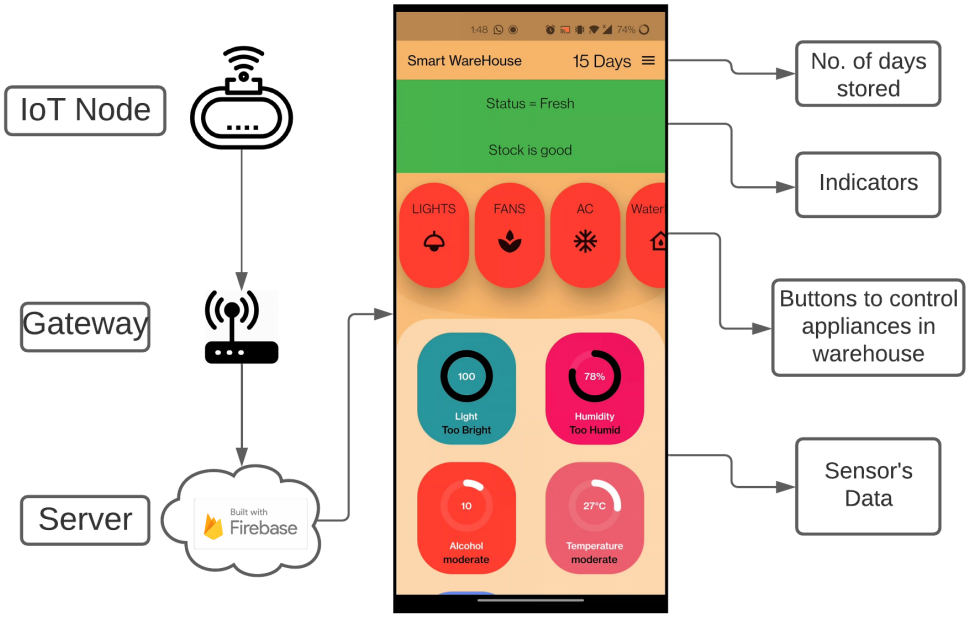


Fig(6) History and Settings page

The application mainly consists of 3 pages,

The home page where you can see all the current readings of the data. Home page consists of 4 bodies, the top tab where you can see the date, below which there are the switches for the for the environmental factors such as Lights, fans, AC and waterflow, under that we can find the current readings from sensors
The settings page where you can change the starting date of the storage and open the ML model.
The history page where you can see all the previous history of the readings.

We have designed a mobile application that has 4 bodies in the upper part that includes Lights, fans, AC and water flow. By pressing this button the values can be changed in the cloud server.In the middle body we have all the values of light intensity, humidity, temperature and alcohol that is measured by the sensors.In the upper part we have whether the stock is empty or full and that will be measured by the load sensor.We have also added number of days the fruit is kept in the warehouse in upper right side and added machine learning algorithm to create graphs and visual representation about how to minimize the cost of keeping the fruits .



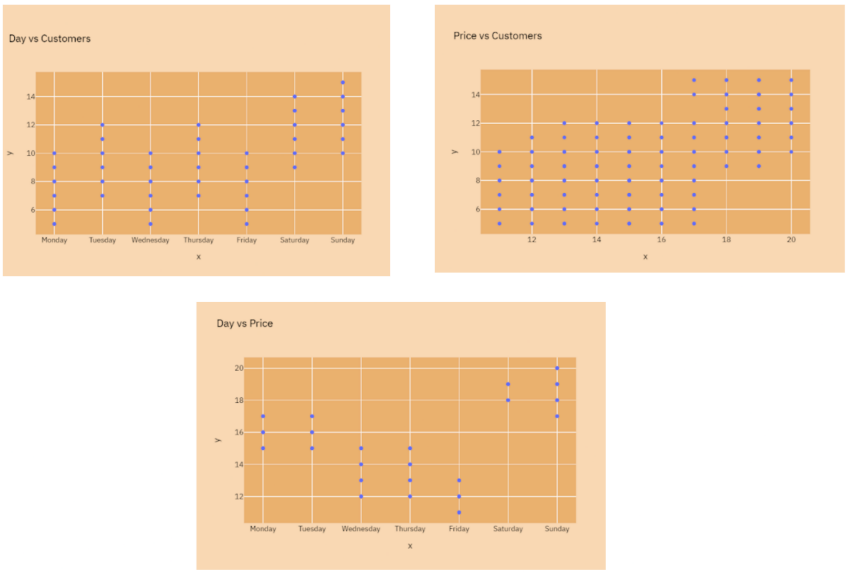
Fig(7) Smart Warehouse user-friendly Application

The Machine Learning Model, ML model basically provides us with a smart educated prediction related to the fruits and vegetables spoiling date, and the most profitable date for selling the stored items.

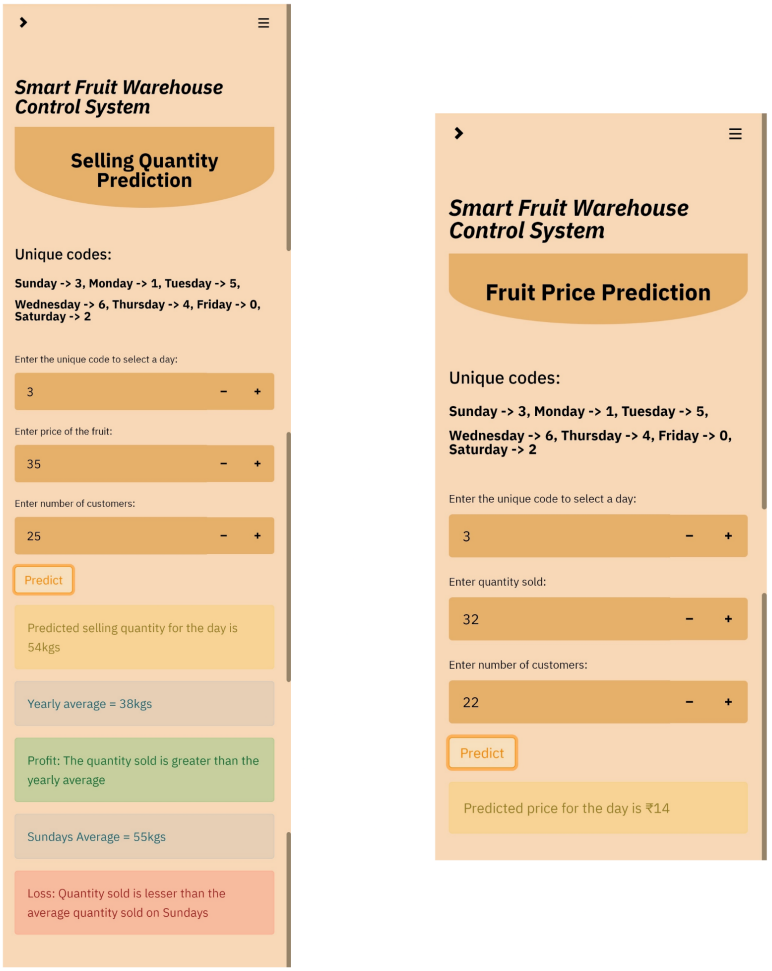
ML is prepared using a python backend which uses gradient boosting regressor algorithm which was trained using 1 year sample data consisting of the quantity sold, customers visited and the price of 1kg of fruits each day, we can predict the selling quantity of the fruit on a particular day.

Just by entering the unique code of the selected day(code for each day is shown in the figure below), price of the fruit and number of customers visited, we predict the quantity of the fruits sold on that day. And it also compares the quantity sold on the particular day with the yearly average and see whether it is profit or loss.Along with this it also compares the average of the fruits sold on the particular day throughout the year and determines whether it is profit or loss. We can also predict the price of the fruit on a particular day by entering the unique day code , the quantity sold and number of customers.

We are using machine learning to do these predictions. Machine learning has the ability to create accurate models to guide the future actions it discovers patterns that we have never seen before.And the data we are using is dynamic, hence these predicted values are more accurate than the basic calculations.



Fig(8) Predictive Analysis of Days, Price and Customers for Multi Regression



Fig(9) Predicting Selling Quantity and price of fruits using Machine Learning

5. Comparison of the solution with existing solutions

- The proposed system is fully centralized, i.e., the warehouse can be controlled and monitored from anywhere around the globe.
- The solution provides an android app that gives a rich user interface to interact with the system.
- The proposed system also saves the data in the form of history for all sessions for any future references.
- The weight of the fruits is calculated and notifies the user when the stock is low.
- Machine learning is being used to make predictive analysis to make the management easier and profitable.
- The platform is hooked up with algorithms that take care of the duration of storage and will notify the user on completion of the duration.

- It sets the parameter values (Temperature, humidity, and light) based upon the type of fruit stored and can detect any malfunctions whatsoever and notifies the user.

6. Conclusion

The Internet of Things is the network of physical objects that contain embedded technology to sense or interact and communicate with their internal states or the external environment. A significant chunk of IoT applications involves sensing in one form or the other. Almost all the applications in IoT sensing form the first step. Incidentally, actuation forms the final step in the whole operation of IoT application deployment in most scenarios. When the planet is employed to control automatic machines, our solution provides a robust, efficient, and scalable alternative to the standard warehousing techniques. Humans operating machines provide desired output at the value of an increased chance of errors. We've introduced a way of automating the control of warehouse environment parameters, thereby reducing manual mistakes nearly to zero, by providing the optimum number of days for storage of products within the warehouse and eliminating the probability of over-ripening of the fruits thanks to prolonged storage also as making their storage is economically feasible. Centralized monitoring and processing unit makes the supervision of the warehouse easy without overloading the local microcontrollers. That being so, the answer provides the modern-day alternative to traditional warehousing systems overcoming all their shortcomings. In the future, the solution can enjoy artificial intelligence with machine learning on the recorded data. Machines will be learning warehousing patterns and thus can estimate the number of days a fruit will remain of quality under certain environmental conditions. Also, the machine learning algorithm helps in predicting the outcomes of price and selling quantity hence making the management predictions easy and profitable.

➔ Machine Learning algorithm and dataset
➔ IoT Based Smart Warehouse Management System Video