Smart Food Grain Quality Monitoring System

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Abstract:- The given paper proposes a solution to the damage caused to the wheat grain via a sensor enabled wireless IOT network. The prototype uses Arduino UNO board and NODEMCU ESP8266 for obtaining and transferring data. The data of various parameters (like humidity, temperature, moisture, CO2 gas and pH) are collected and is then sent to the Google's Firebase Cloud for data storage and management. From there, it is then sent to the ARIMA Machine Learning Model for prediction of relative humidity for the next five days which helps us to analyse the microbial activity inside the silo. Additionally, an ultrasonic sensor is used to detect the level of wheat grain in silo so that illegal activities like corruption can be prohibited. All the data collected, and results obtained is presented on an online dashboard for easy visualization via graphs and appropriate conclusions. The simulation of a real–time monitoring system along with the proposed shelf life as researched through different papers, journals and publications is also displayed on the online dashboard.

Keywords:- *Arduino, NodeMCU ESP8266, Firebase, Machine Learning, Data Analytics, ARIMA Model, Grading & Classification, Web Display, Data Visualisation.*

I. INTRODUCTION

India's grain production is constantly increasing year by year, with a total food grain production estimate of 316 million ton in the country during the 2021-22 crop year (Refer Fig-1). Out of which, the total production of wheat during 2021-22 is estimated at a record of 111 MT which is higher by over 7 MT than the average wheat production of 104 MT [1].

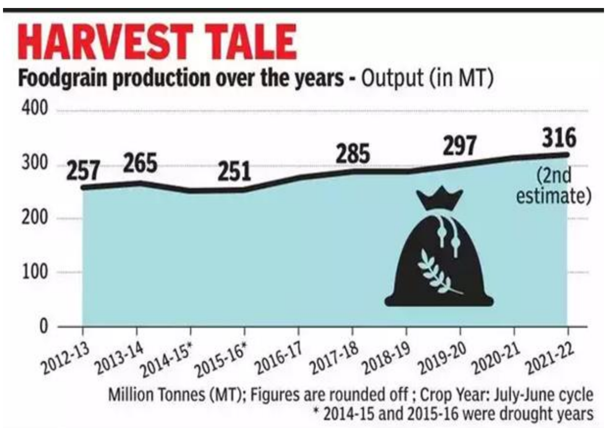


Fig. 1: Estimated Food grain production in the year 2021-22 (Credits: Food Ministry of India)

In a semi-developed country like India, we still monitor the food grain's health using conventional methods, which leads to a great loss of food grain due to storage. According to Food Corporation of India (FCI) during 2017-18 around 0.025 Lakhs tonnes of food grain got damaged and during 2018-19 this get increased to 0.05 Lakhs tonnes. According to India Today and other well-known media sources, the actual spoilage accounts to 4.65% to 5.99% of the total procurement [2]. Factors like insufficient assistance, lack of cold storage, procurement challenges, incorrect transportation, and undeveloped marketing channels results in 25 to 30 percent waste (Refer Fig-2). Therefore, it becomes critical to provide an appropriate route through which the most efficient output reaches every person. Therefore, there is a need for a network to detect the various parameters to determine the shelf life, nutrient level and health of food grain so that spoilage can be reduced.

By implementing the Wireless Sensor Network (WSN) technique, a Smart Food Grain Quality Monitoring System based on IoT is proposed. The basic working model includes the sensors collecting the data of the parameters (physical and chemical) inside the storage system which mainly contribute to the spoilage of food grains.

If any variations are detected, it can be communicated to the user so that necessary control measures get applied.

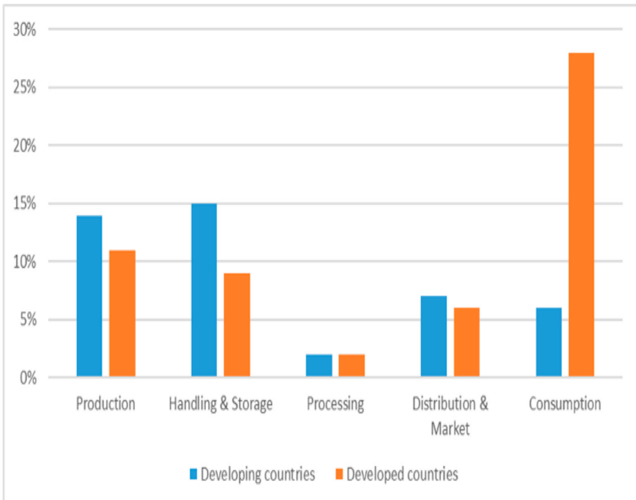


Fig. 2: Wastage Statistics of Wheat grain via various factors in developing nations (Credits: MDPI)

II. DESIGN METHODOLOGY OF THE FOOD GRAIN QUALITY MONITORING SYSTEM

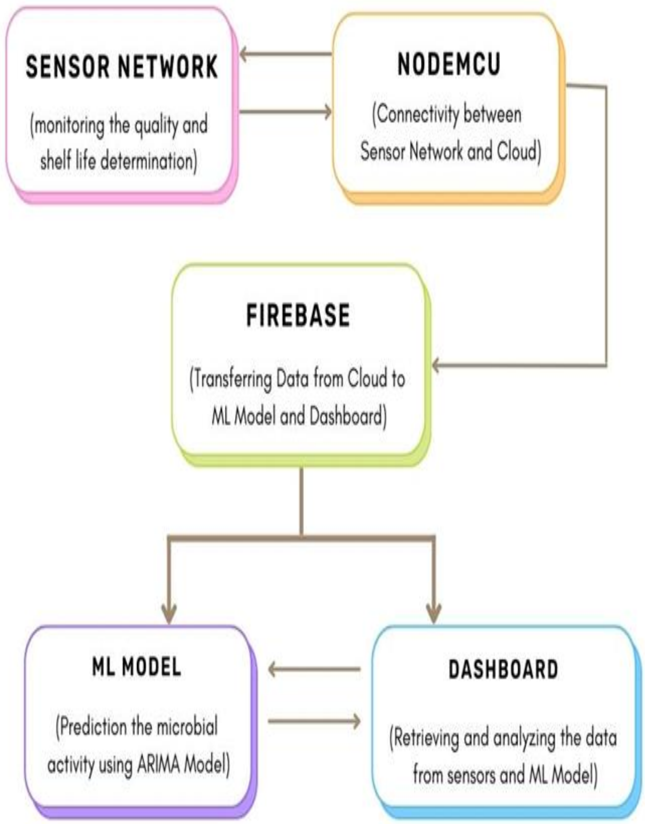
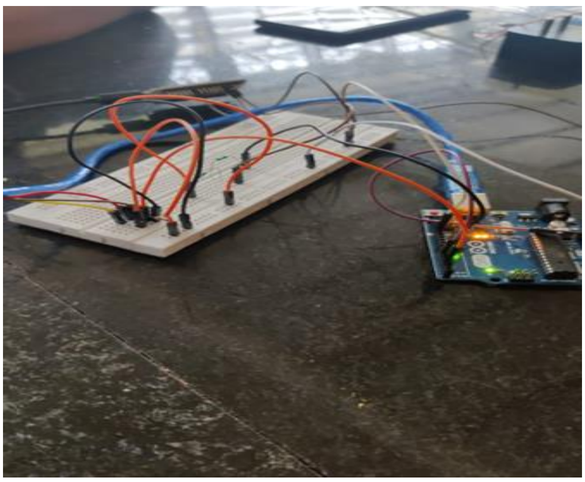


Fig. 3: Design Methodology of the Food Grain Monitoring System

- **Sensor Network:** An Arduino based Sensor Network has been deployed with DHT11, LM35, MQ3 sensors to detect the levels of various parameters like humidity, moisture, temperature and CO2 level respectively (Refer Fig-3)of the silo. Based on the above parameters, shelf life can be calculated and microbial activity inside the silo can be obtained. Along with these, an ultrasonic sensor has been deployed to monitor the level of wheat grains present in the silo to restrict illegal activities like corruption [3].



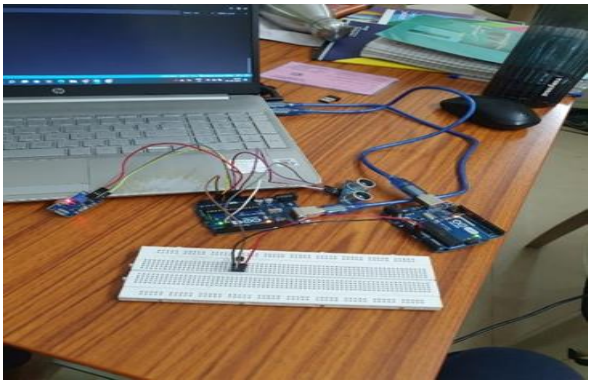


Fig. 4: Integrated Sensor Network Along with NodeMCU ESP8266

- **Node MCU:** Once the sensor Network is implemented, the IoT enabled system is integrated with a NODEMCU Model also known as ESP8266 module to transfer the data seamlessly from the sensors to the Firebase Cloud(Refer Fig-4).
- **Firebase:** Once the Firebase receives real time data from the NodeMCU Micro-controller, it is now ready to establishes connectivity between Cloud and ML Model and, Cloud and Online Dashboard(Refer Fig-3).

➢ Working of the Firebase Model:
- ✓ NodeMCU and Arduino Uno are connected using a concept known as I2C (Inter Integrated Circuit) Communication. I2C stands for the inter-integrated controller(Refer Fig-5).
- ✓ This is a serial communication protocol that can connect low-speed devices. It is a master-slave communication in which we can connect and control multiple slaves from a single master.
- ✓ NodeMCU acts as the master mode which has an address of the slave device. Slave device receives requests from Master.
- ✓ The slave device (Arduino Uno) thus sends the sensor data to the Master Mode.
- ✓ NodeMCU sends this sensor data to the Firebase. To establish proper communication with the Firebase's Real-Time Database, fingerprint of the Firebase API was obtained from www.grc.com and the fingerprint was further implemented in the Firebase header file.

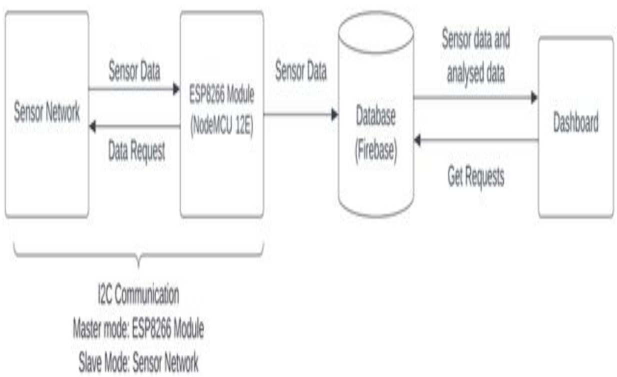


Fig. 5: Working Flow of Firebase

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- **ARIMA Machine Learning Model –** Machine Learning models can be understood as a program that has been trained to find patterns within new data and make predictions. After the real time data is stored in Firebase Cloud, it is then sent to ARIMA ML Model that will predict the relative humidity for the next five days and predict the probable microbial activity that could attack the grains(Refer Fig-6).The algorithm uses the collected real time data and predicts relative humidity for next 5 days to determine any probable microbial activity. ARIMA is an acronym that stands for Autoregressive Integrated Moving Average [4]. It is a class of model that captures a suite of different standard temporal structures in time series data. It explicitly caters to a suite of standard structures in time series data, and as such provides a simple yet powerful method for making skilful time series forecasts.

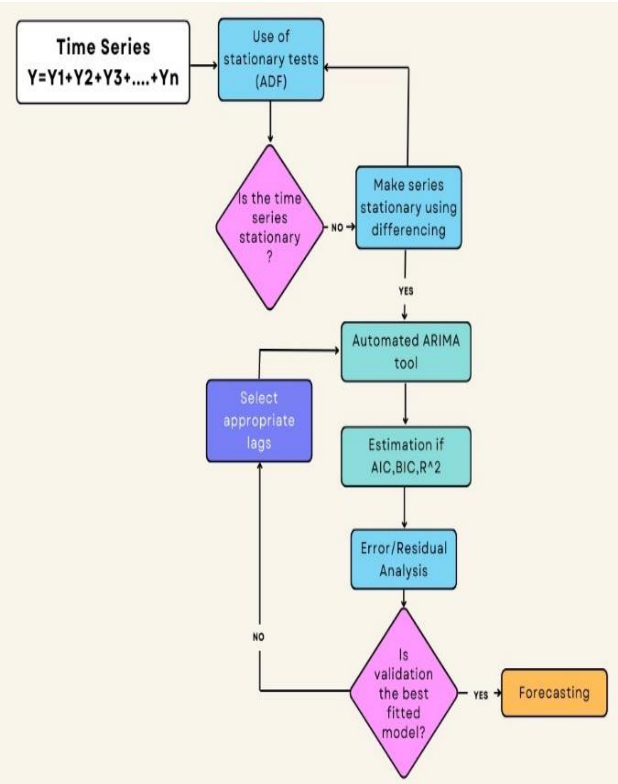

Fig. 6: Working Flow of ARIMA Model

- **Online Dashboard:** The data collected via the sensor network and results obtained via the ARIMA ML Model is represented in the online dashboard created via React Application on Visual Code Studio(Refer Fig-7). The monitoring is then performed through a dashboard. A dashboard provides easy visualisation of values to the users for continuous monitoring.

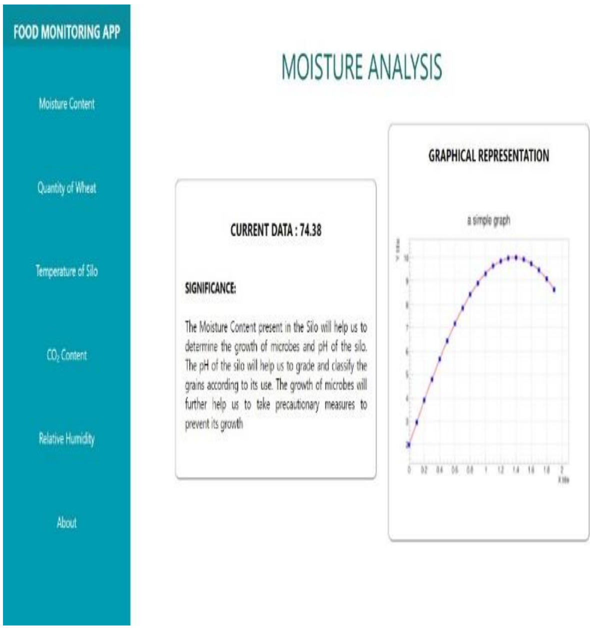

Fig. 7: Online Dashboard using React

Features of the online dashboard are:

- Contains separate tabs for individual parameters, providing easy to use UI for the potential users.
- Extracts the values of various quality parameters from cloud to present a consolidated status of wheat grains.
- Pictorial representation in form of graphs will be depicted to observe the trend of values of parameters.
- Conclusions from the Machine Learning model is also shown to make appropriate conclusions.

III. WORKING OF THE DEVICE

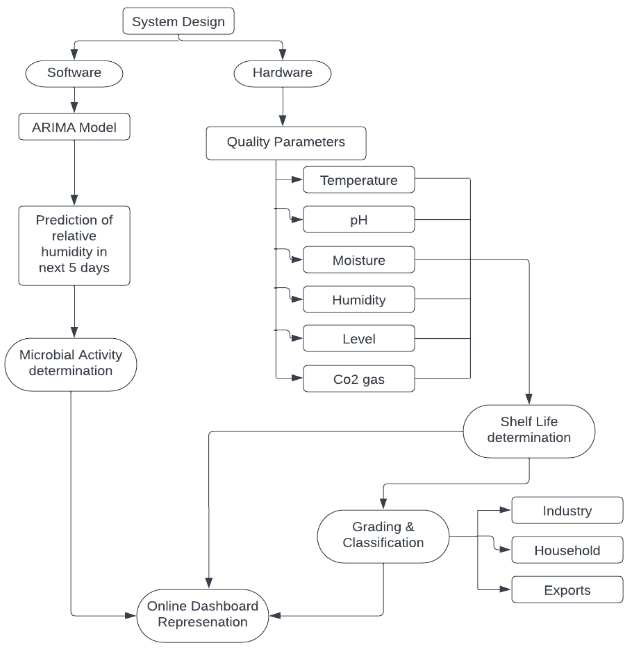

Fig. 8: Work flow diagram of the device

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- Step-1: The integration of the sensor network is kept at such a place in the silo from where the optimum readings could be obtained for all the different parameters such as humidity, pH, moisture, CO2 level and the level of wheat grain.
- Step-2: After this, the code runs in the Arduino IDE platform by selecting appropriate COM port. From there, the data of the parameters obtained from the sensor network are displayed in the serial Monitor.
- Step-3: Once the serial Monitor show the data of the various parameters, ESP8266 Code runs in the same Arduino IDE Platform as interfaced with the sensor network so that it can communicate with the sensor network via I2C communication and retrieve those values from the serial monitor and store it.
- Step-4: The data stored in the ESP8266 Module is now ready to establish a communication with Firebase Cloud to send the data via master-slave concept. The firebase cloud acts as a platform for real time data storage and management. It further establishes relation between cloud and ML Model as well as Cloud and Online Dashboard
- Step-5: From the Firebase, next step includes sending the data of the DHT11 sensor to the ARIMA model for prediction of relative humidity for the next five days. This relative humidity obtained is essential to determine the growth rate of microbial activity in the silo.
- Step-6: Once the results from ML Model are obtained, it is directly sent to the Fire base again with appropriate conclusions
- Step-7: After this, the next step is to send the data obtained from all the sensors and results retrieved from the ARIMA model to the Online Dashboard.
- Step-8: The Online Dashboard represents all the data and results in form of graphical representation for easy analysis of data and continuous monitoring of the wheat grain.
- Step-9: Once the data is represented in the online dashboard, the results tab include the specific data such as shelf-life of the wheat grains, microbial activity and grading and classification of the wheat grains according to Table-1.
- Step-10: Once the specific data is released, appropriate precautionary measures can be taken to prevent microbial growth and grains could be classified easily so that their wastage is reduced to a proper extent.

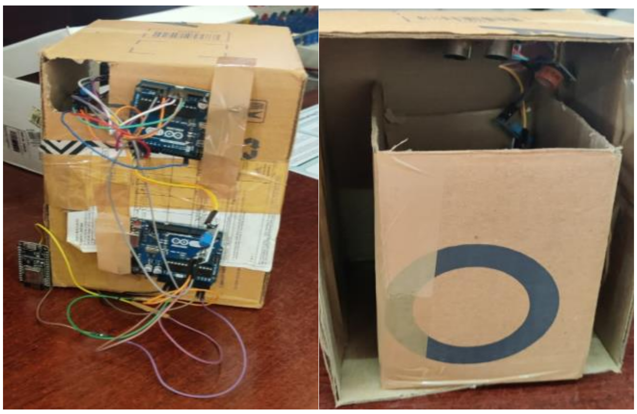

Fig. 9: Device Setup of Smart Food Grain Quality Monitoring System

Shelf Life	Humidity	Moisture	Temperature	CO2 gas	Fungal Activity	pH Value	Grading
<4 Months	<58.8%	>83.9%	>40 C	>5%	Mold growth and chemical degradation	Around 6.05	Beverage Industry
5-11 Months	>=58.8 & <=76.2	>=52.2 & <83.9	5 C to 40 C	2%-5%	Normal bacterial growth	Around 5.87	Household
>12 months	>76.2	<52.2%	-20 C to 5 C	<2%	Reduced fungal activity	Around 5.40	Exports

Table 1: Shelf-Life determination, Microbial activity prediction& grading of wheat grains

IV. TEST CASES AND RESULTS

A. *Test Case-1:When the value obtained from DHT11 Sensor for Humidity is less than 58.8% and Moisture is greater than 83.9% but value from LM35 sensor for temperature is greater than 33°C and value from MQ3 gas sensor is greater than 5%.*

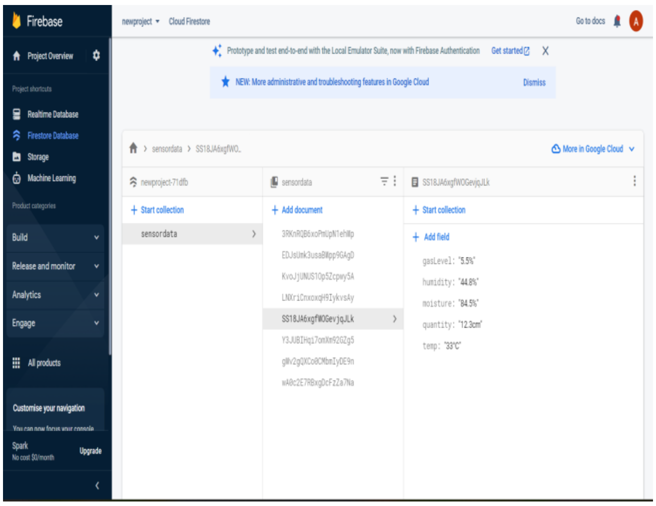

Fig. 10: Sensors Value on firebase

Prediction of relative humidity for next 5 days

2022-06-01 00:00:00: 33.49112089251385
2022-06-02 00:00:00: 45.20282091535584
2022-06-03 00:00:00: 43.69195117267386
2022-06-04 00:00:00: 53.96456931566928
2022-06-05 00:00:00: 49.13226329910872

Fig. 11: Relative Humidity Prediction for the next 5 days

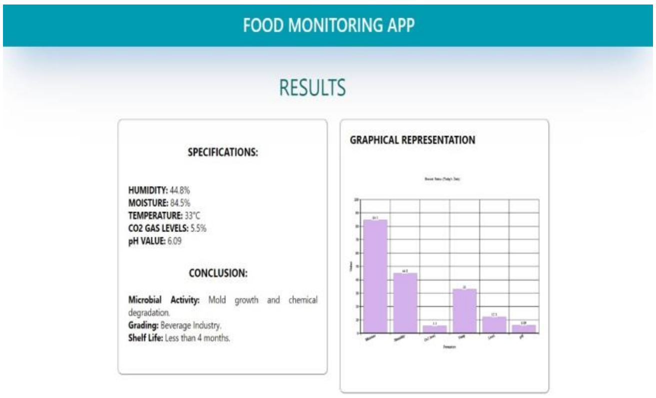

Fig. 12: Online Dashboard with grading, shelf life and microbial activity

B. *Test Case-2: When the value obtained from DHT11 Sensor for Humidity is in the range of 58.8% to 76.2% and Moisture is in the range of 52.2% to 83.9% but value from LM35 sensor for temperature is in the range of 5°C to 40°C and value from MQ3 gas sensor is in the range of 2% to 5%.*

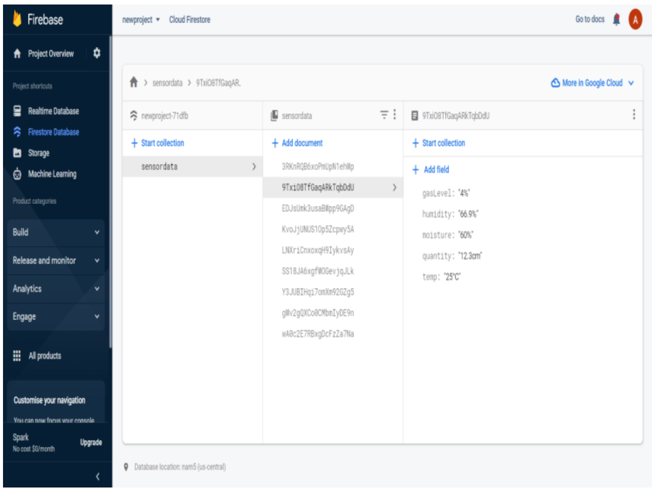

Fig. 13: Sensors Value on firebase

Prediction of relative humidity for next 5 days

2022-07-07 00:00:00: 66.98224178502777
2022-07-08 00:00:00: 90.40564183071167
2022-07-09 00:00:00: 87.38390234534772
2022-07-10 00:00:00: 67.92913863133856
2022-07-11 00:00:00: 98.26452659821744

Fig. 14: Relative Humidity Prediction for the next 5 days

Fig. 15: Online Dashboard with grading, shelf life and microbial activity

C. *Test Case-3: When the value obtained from DHT11 Sensor for Humidity is greater than 76.2% and Moisture is less than 52.2% but value from LM35 sensor for temperature is in range of -20°C to 5°C and value from MQ3 gas is less than 2%.*

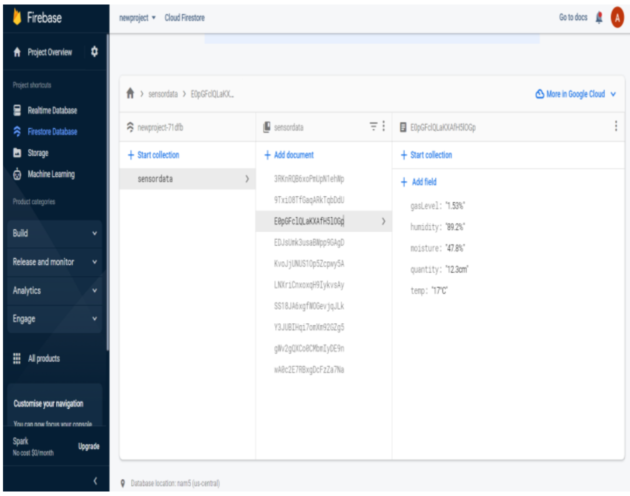

Fig. 16: Sensors Value on firebase

Prediction of relative humidity for next 5 days

2022-07-21 00:00:00: 46.37232123578841
2022-07-22 00:00:00: 62.58852126741577
2022-07-23 00:00:00: 60.49654777754841
2022-07-24 00:00:00: 74.72017289861901
2022-07-25 00:00:00: 68.02928764491978

Fig. 17: Relative Humidity Prediction for the next 5 days

Fig. 18: Online Dashboard with grading, shelf life and microbial activity

V. CONCLUSION

This project has been successful completed as the circuit made worked fine and all the hardware components worked efficiently. DHT11 sensor was used to measure moisture and humidity, MQ3 for the CO2 level in the atmosphere and the LM35 to detect the temperature. All these parameters were the further used to determine an appropriate range of pH in the silo. Furthermore, this combined all together provided the value that can be used to find out if the place is safe to store grains and also the current health status of the grains [5]. Then this project uses an ESP module of type 8266 and version 01 to send value to the cloud service of Google's Firebase. After this, value is retrieved by the service and sent to the ARIMA Machine Learning Model in the Kaggle Kernel where the relative humidity was accurately predicted for the next five days which indicated and informed about the microbial activity in advance. The results thus obtained from the sensor network and ARIMA model were displayed on the online dashboard with graphical analysis and proper conclusions. This interface is very efficient and is used to setup a unidirectional contact between the user and the hardware [6]. All the content displayed in the hardware is efficiently transferred to the online dashboard and the values from there can be used by any person with the login credentials and use for his benefits. This web interface and hardware system can be used up by small farmers wanting to know the status of the health of their produce and by a trader who can easily access the storage place condition and read up the values. Therefore, making the whole device very useful.

VI. FUTURE DEVELOPMENTS

The future scope of the proposed work is as follows:

- To incorporate parameters for various types of grains, as now the model only detects the health of wheat.
- To increase the period of time which shows the real time values of the quality of the wheat stored, as for now the data is recorded for a period of three months only.
- To get more precise and accurate readings of the parameters.
- Publication of Website in regional languages to support the farmers

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