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IoT Based Humidity and Temperature Control System for Smart Warehouse

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Highlights

- To minimize the food loss and increase food quality and safety using IoT.
- Farmer receives information time to time regarding their stored grain and fruits.
- A system that assures extra safety for food and Grain.

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Keywords

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Abstract

In daily life, vitamins fruits and vegetables play a very important role in human life. The farmer produces grains or vegetables in huge quantities. Due to lack of storage problem farmer suffers. It is necessary to store all these things in a special warehouse. Thus, improper storage of grains or fruits is essential to meet the increasing demands. Storage time and fruit quality are greatly influenced by storage environmental factors. Therefore, it is important for the fruit storage environment to perform multi-parameter monitoring and analyze the collected parameters and then regulate and control. The quality of grains and other perishable goods kept in a warehouse usually deteriorates due to lack of monitoring and proper maintenance of their required suitable conditions in such a large area. The proposed methodology deals with the storage of grains, fruits, etc., and to identify their temperature and humidity patterns so that they will not be degraded. Establishing the environment in relation to the nature of the crop so as to determine an optimum threshold with an appropriate pattern of monitoring and change. The main goal of this research article is to provide solutions to prevent rotting of grains and fruits in the storage area.

1. INTRODUCTION

India is a country where agriculture plays a significant part in the economy. Farmers confront a slew of issues each year as a result of storage restrictions and a lack of appropriate food monitoring. Warehouses are used to keep things in order. The monitoring of the conditions of a warehouse according to the suitable atmosphere of the logistics is a very tough task to manage [1] . Storage is not the problem but maintaining the quality of the product is a major problem. In order to ensure the quality, we have to meet the required optimal temperature and humidity of the product. If these requirements are not fulfilled according to the optimal range, then the quality of the product will be degraded for sure. The economy and life fully depend on the agricultural and therefore it very essential to store food grains with proper precautions and care. The storage area is most important to farmers, as the better the storage area, the better will be the quality of food grains [2]. The state-run warehouses hold just a small portion of the food grains. A substantial portion of the harvests are unable to be stored due to a lack of adequate storage facilities. Maize, wheat, and rice are among the crops grown across the world. However, the market strategies change day by day in terms of supply. Due to this issue loss of government is around Rs.1.5 lacks per year. The kind of storage structure, pH, moisture, temperature, adequate light, humidity, and other environmental variables all impact the natural contamination of food grains. The food's worth depreciates as storage duration rises. As a result, there is a concern about food safety [3-4]. Various conventional storage techniques were implemented, requiring a large manual approach that takes more time and is inefficient. The lack of a multi-parameter monitoring system was another flaw. So the IoT-

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based food grain monitoring system not only seeks to create a multi-parametric system that assists in reducing loss due to different variables such as moisture, ageing, and decaying, but it also saves time and money. Traditionally, there were several conventional ways for keeping fruits and vegetables that needed a lot of human labour every now and then, which was both time-consuming and inefficient. Another disadvantage of conventional warehouse installations is that multi-parameter monitoring was not prioritized. It is critical to maintain ideal storage conditions for fruits and vegetables in order to preserve harvests from moisture loss, ageing, and deterioration. A numerous feature of warehouse in terms of environment monitoring such as cheap cost, ease of use, exact measurement, and remote auto monitoring is urgently needed. It is critical for the fruit warehouse environment to conduct multi-parameter monitoring, evaluate the data, and then make regulatory and control decisions. However, at the moment, the approach for monitoring the environment in fruit storage relies mostly on manually observing the thermometer and humidity meter. Monitoring of local temperature and humidity through wired monitoring system in storage place is not always possible due to lack of space constraints. In order to quickly and easily establish well-organized warehouse planning, we need a specific mechanism.

1.1. Objective of Proposed Work

The main goal of proposed method is described as follows.

- To minimize the food loss and increase food quality and safety using IoT.
- It is helpful to design and develop a real-time application for warehouse.
- Farmer receives information time to time regarding their stored grain and fruits.
- To develop a system that assures extra safety for food and Grain.

The rest of the paper from Section 2 to Section 7 is structured as: Pertinent works, tools and technique, proposed work, experimental results, advantage of proposed work, and conclusion respectively.

2. PERTINENT WORK

Kumar S et al. [5] introduce the importance of IoT that play a important role in smart city, smart and smart lifestyle, and also described a smart system that monitors the grains in storage areas. The system monitors parameters like temperature, humidity and many more to control the damage to the grains. Also, this system detects the insects, two factors which harm the grains are also controlled by temperature, humidity and light. Rajesh Kumar Kaushal et al. [6] suggested an Internet of Things system to avoid food contamination during storage and transit. In the system proposed by K Mohan Raj et al. [7] , the architecture of the system is an IoT-based smart warehouse monitoring system in which Vibration, humidity, temperature, and fire sensors are among the several types of sensors utilised. Alexandru Popa and colleagues [8] presented an integrated dietary monitoring approach. Vacuum-packed goods are compatible with the system. A real-time intrusion and tracking system was suggested and built by Sipiwe Chihana et al. [9]. Suryawanshi VS et al. [10] proposed a system for food grain storage that timely monitors the temperature and humidity, which are the main two factors that can affect the quality of grain. In this, the overall system consists of two components, the host computer, and the lower computer terminal. Yanghui O et al. [11] this paper proposed a warehouse environment monitoring system with some important parameter like air temperature, and relative humidity. The propound article design for a smart storage of warehouse. This system can measure multipoint temperature and humidity real-time data by using the temperature and humidity sensor. Karim AB et al. [12] proposed a kind of storage that can preserve raw foods for a while. In this paper, the proposed system monitors the temperature and humidity using different IoT sensors. Sujeetha et al. [13] clearly discuss ecological conditions and any type of error that can cause misfortune in the pharmaceutical and horticultural enterprises. In this paper, the system can measure the temperature and humidity, so that the productivity in the agricultural sector can increase rapidly. Today’s weather forecasting system is based on Satellite and Radar. But this system closely monitors the agricultural field including the humidity, temperature, moisture, light intensity, and water leakage. Rai BK et al. [14] focus the importance of monitoring in today's life and the importance of Internet of Things (IoT) and related technologies. The proposed system uses IoT Technology and consists of Arduino based monitoring and uses NodeMCU wifi module. The system can read the data from the sensors and allows different devices controlling. Parwez S et al. [15], Due to insufficient infrastructure and a very inefficient supply chain, Indian agriculture has a number of challenges in terms of food security. Rai B.K. et al. discussed issues in prescription and report analysis for healthcare [16]. The difficulties in each system of the agriculture supply chain are examined in this study. Chaturvedi DBK et al. [17] discussed the losses of food grain in the country due to the lack of storage facilities and also poor management of the storage available. This paper also highlights the problem of wastage of food grains that are stored against the limited amount. Rai B.K. et al. [18] insisted the importance of Open-source intelligence for the gathering and retrieval of data from online sources which can be used for several methods. Sazia Parvin et al [19] described the grain storage system with monitoring and control. A wireless transceiver and microcontroller-based monitoring system is presented by Li Lijuan et al. [20]. The system presented in the literature review exemplifies the researchers' efforts in the field of food management. However, the temperature and humidity levels in the food management system must be checked on a regular basis. This paper also discusses the various challenges and issues of IoT. Rai B.K. et al. [21] discussed issues for maintaining privacy and security in any information system.

3. TOOLS AND TECHNIQUES USED

3.1. Sigmoid Function

We have used sigmoid function to predict the probability between the range of 0 to 1 and this function is specially utilized in models that need us to estimate probability as a result. Also, its range is between 0 to 1, which means it exists within this range only. Equation (1) describes for the sigmoid function, where F(x) is a sigmoid function and e is a Euler function

$$F(x) = \sigma(x) = \frac{1}{1+e^{-x}} \cdot \tag{1}$$

3.2. Model.fit ()

The entire set of data can be fitted into the memory using fit () function. The outcome is accurate if the model is fitted properly. The assumptions are being made for the training of data. This is an essential process required to gain a high level of accuracy for our model. Below is the code to fit our model is describe in Figure 1.

```
fit(object, x = NULL, y = NULL, batch_size = NULL, epochs = 10,
  verbose = getOption("keras.fit_verbose", default = 1),
  callbacks = NULL, view_metrics = getOption("keras.view_metrics",
  default = "auto"), validation_split = 0, validation_data = NULL,
  shuffle = TRUE, class_weight = NULL, sample_weight = NULL,
  initial_epoch = 0, steps_per_epoch = NULL, validation_steps = NULL,
  ...)
```

Figure 1. *Simulation Code for Model.fit ()*

Where, **object** is the model which we have to train.
x is our training data, and **y** is our training labels.
batch_size will be automatically set to 32 by default and its store any integer value or even null.
epochs is the number of times we have to run the code.
verbose specifies verbosity mode(0 = silent, 1= progress bar, 2 = one line per epoch).

shuffle means if we want to scuffle our information or not before each time the programs run.
steps_per_epoch means the number of phases taken between two epochs.

3.3. Times Series

Time series forecasting is a method which we are using for the prediction of values in future by the help of previous data. This method is mainly used for weather prediction, prediction of stock prices etc. The process of creating a model for predicting future values based on recent and previous time series data is known as time-series forecasting. Time-series data has four components.

- **Trend:** Generally, trends mean increasing or decreasing of data value in linear and nonlinear fashion.
- **Seasonality:** It is a character of time series data when it experiences regular and predictable movement after a fixed period of time.
- **Cyclic:** When the data experience up and down, a cyclic pattern emerges.
- **Irregularity:** The remaining of time series after the trend-cycle and serial module are detached.

3.4. FB Prophet

This tool is used for forecasting and displaying the future values on a daily, weekly, monthly or yearly basis. Prophet is open-source software announced by Facebook’s Core Data Science team. The Advantages of FbProphet are as follows.

- It is Fast and Accurate
- No manual effort is required, it is fully automatic.
- It is available in two languages i.e R and Python.

FBProphet is intriguing, complex, and simple to use, with the help of this model we can easily predict the good forecast output with little effort.

3.5. Streamlit

Utilizing Streamlit, we are visualizing code output while examining data. Build ML tools that can be utilized to examine data through clicks and sliding bars. Then this data is used for two purposes one is for forecasting with the help of prophet time series forecasting method displayed using Streamlit. The advantages of using Streamlit tools are as follows.

- It accepts Python scripting and No HTML knowledge is needed.
- Less code is required to create a beautiful application.

Streamlit can be simply installed with the following command: **pip install streamlit**

3.6. Grafana

Grafana is a multi-platform open-source systematic and interactive visualizatioGrafana is a multi-platform, open-source online tool for systematic and interactive visualisation. Grafana offers a wide range of graphs, charts, and alerts. Grafana integrates with a wide range of data sources, including Graphite, Prometheus, Influx DB, ElasticSearch, MySQL, PostgreSQL, and others. Grafana's open source approach also allows us to create custom plugins for integration with a variety of data sources. Technically known as time series analytics, the technology assists us in studying, analyzing, and monitoring data over a period of time. It provides relative data that allows us to track user activity, application behavior, and pre production environment. It contains a feature for dynamic dashboards, which allows us to display graphs, bar graphs, and alerts. Grafana dashboards are designed to bring data together in an efficient and structured manner. Through searches, insightful visualizations, and alerts, users may gain a deeper understanding of their data's metrics. Grafana dashboards not only provide analytical meaning to data gathered from many sources, but they can also be shared with other team members, allowing you to examine the data together. Figure 2 depicts a generic Grafana Dashboard.

Figure 2. *Interactive dashboards in Grafana*

3.6. K-Means Clustering

Clustering methods are different types; K-mean clustering is one of them. It is based on unsupervised learning algorithms. In this method there are unlabeled data set are lies in different cluster. K define the number of pre-define cluster. The number of cluster depend upon the value of K. if K= 1 then the number of cluster is one and if K=2 then the number of cluster is two and so on.

The workings of the K-means algorithm are as follows:

- K is the number of clusters to specify.
- Initialize the centroids by shuffling the dataset and then picking K data points at random for the centroids without replacing them.
- Keep iterating until there is no change to the centroids. i.e., assignment of data points to clusters isn’t changing.

The working of K-means clustering and formation of clusters in K-means Clustering is shown in Figure 3.

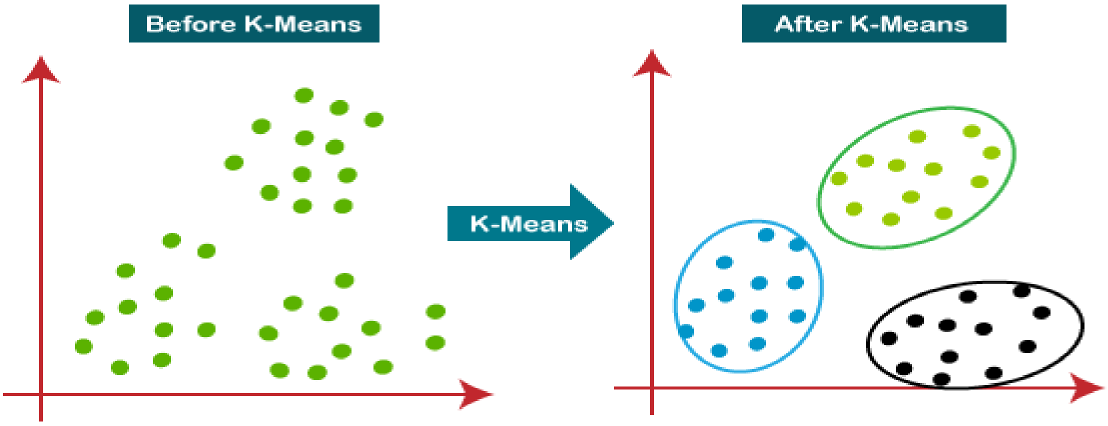

Figure 3. *K-Means clustering*

The main tasks in this clustering algorithm are to select the correct values of k. If we choose the k values at random, it might be accurate or incorrect. If we pick the incorrect value, it will have a direct impact on the performance of your model. There are two techniques for determining the correct value of k. Following are the two methods for selecting right value of k.

- Elbow Method
- Silhouette Method

3.7. NodeMCU

NodeMCU stands for Node Micro Controller Unit. It is an open source software and hardware development kit. It is a system designed on a chip for IoT applications. It is a microcontroller with Wi-Fi capability. The range of the Wi-Fi can be increased using repeaters. To utilise NodeMCU for IoT applications, we must understand how to write/download NodeMCU firmware on NodeMCU Development Boards, and where this NodeMCU firmware will be obtained according to our needs. The NodeMCU is shown below in Figure 4.

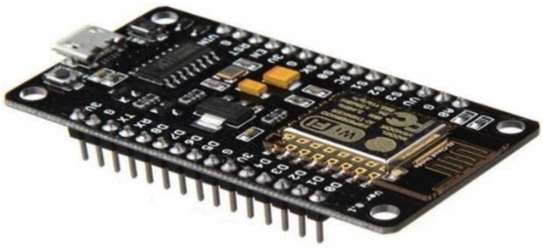

Figure 4. *NodeMCU*

3.8. DHT-11

It is a low-cost sensor for measuring the temperature and moisture digitally. This sensor is interfaced with a micro-controller for measuring the instantaneous temperature and humidity of the surrounding atmosphere.

It measures the ambient air with a capacitive humidity sensor and a thermostat and outputs a digital signal on the data pin. The DHT-11 is depicting in Figure 5.

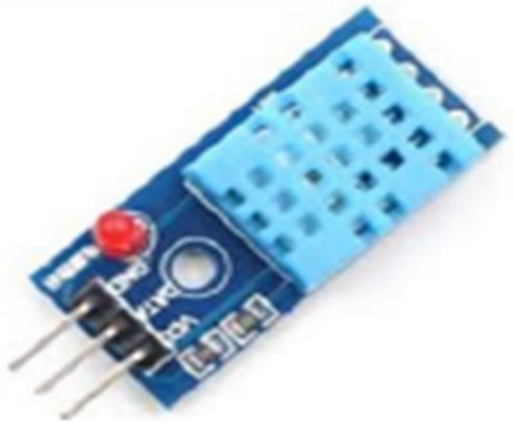

Figure 5. *DHT-11*

4. PROPOSED SOLUTION

NodeMCU and DHT-11 is installed in different sections of the warehouse to record the temperature and humidity of the area. This data is sent through firebase to flask API. The overall setup is to maintain the temperature and humidity according to the threshold of the grain. The readings are visible on the Grafana Dashboard. The website shows the items stored in the warehouse, the instructions for maintaining the appropriate conditions for the grains etc. Also, it shows the locations of the warehouses of the same company around the globe.

4.1. Architecture

The design of the proposed work is shown below in Figure 6. We are using NodeMCU because there is a need to transmit sensor data wirelessly and through wifi is most reliable option as of now. NodeMCU is used for making prototypes of IoT devices in network projects. It is used for low-power battery operated operations and so it is feasible. Other than Bluetooth, LORA, Transmitter and receiver connection, NodeMCU can connect to wifi as well as it can transmit data from sensors it is connected with or else it can receive commands in order to execute any task.

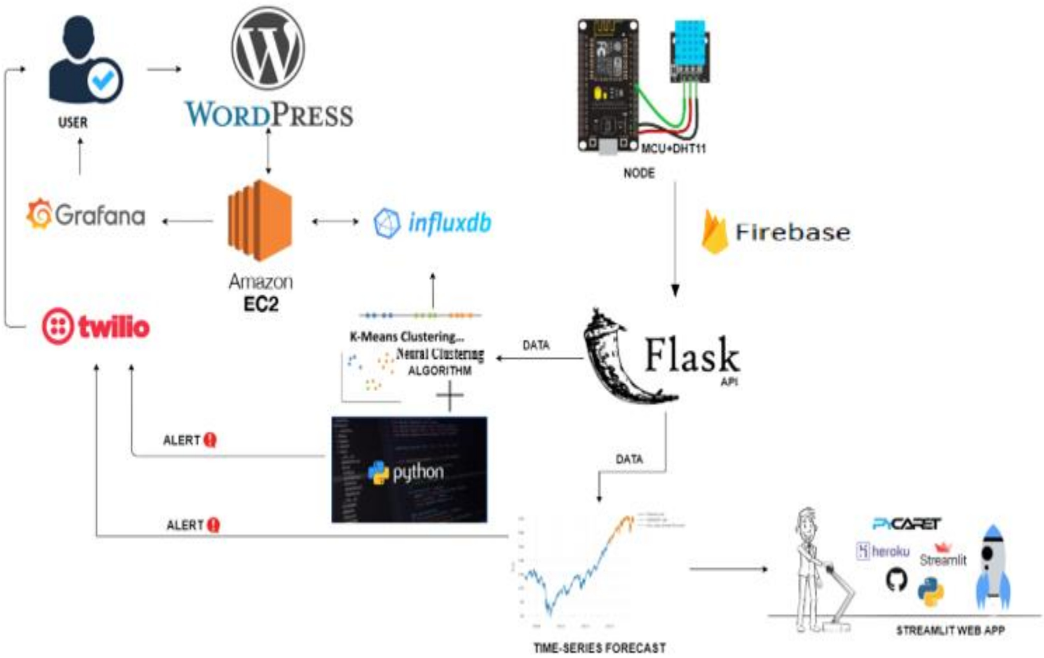

Figure 6. *Architecture of proposed method*

We are using DHT-11 to update the data in every 2 seconds. DHT-11 is a low-cost sensor for calculating digital temperature and humidity. NodeMCU with DHT-11 is installed in each section of the warehouse for taking the readings of the temperature and humidity of the specific area. The data is sent to Flask API through firebase. With Firebase we are syncing the offline and online data by NoSQL database. This boosts alliance on the application data in real time. The main benefits of firebase are speed and also uptime is very good. From the flask API, we are classifying the data into clusters by k-means clustering algorithm and python code for the detection of the condition, if the condition is appropriate or not. The data after clustering is sent to the influx-db (database) which is a time-series database, performs analytics to get faster detection and resolution and it is hosted using Amazon Ec2. The main advantages of hosting the Amazon EC2 are scalability and load balancing.

We are using Amazon EC2 for Amazon Elastic Compute Cloud (Amazon EC2) is a web service that gives safe, scalable compute volume in the cloud. We are using Grafana to visualize the data and can use different graphs and plot so that user can get the best experience. We are visualizing appropriate condition of each segment of the warehouse on Grafana dashboard which is monitored by the user of the warehouse. Grafana dashboard is used for large scale deployment. Also, the data from Flask API is sent for time-series forecast by FBprophets of Facebook for the monitoring of temperature and humidity of the particular area at every second which is shown using Streamlit Web-app.

Using Streamlit, we are creating basic and simple user interface for machine learning model. We can build machine learning tools right from the initial phase. We are visualizing code output while examining data. Then this data is used for two purposes one is for forecasting with the help of prophet time. Series forecasting method displayed using Streamlit. We are using Prophet to predict the time series data based on our model. Prophet is a plan for forecasting time series data established on an additive model where non-linear trends are fit with daily, weekly, and yearly, and holiday effects. Finally, the proposed scheme depicts by flow chat in Figure 7.

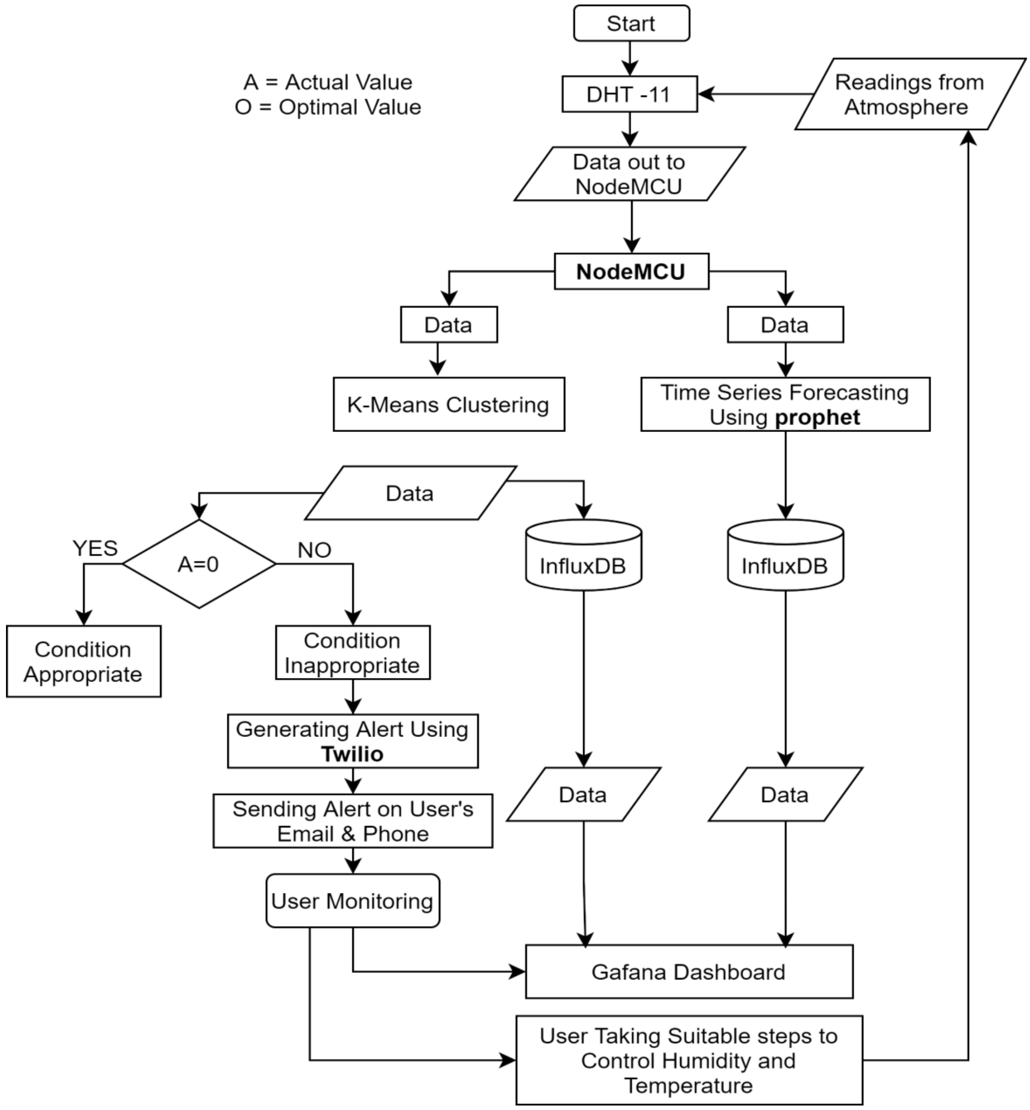

Figure 7. *Flow Chart of Proposed Scheme*

5. EXPERIMENTAL RESULTS

5.1. Model.predict()

On the basis of the trained model, the Python predict () function allows us to predict the labels of data values. Only one parameter is accepted by the predict () function, which is generally the data to be tested. Based on the learnt or trained data collected from the model, it returns the labels of the data supplied as an input.

5.2. Grafana Dashboard

Grafana Dashboard in Figure 8 is showing data readings for Node1 for Wheat Segment. Both Temperature and Humidity readings are displayed Thus the predict() function operates on top of the trained model, mapping and predicting labels for the data to be tested using the learnt label.

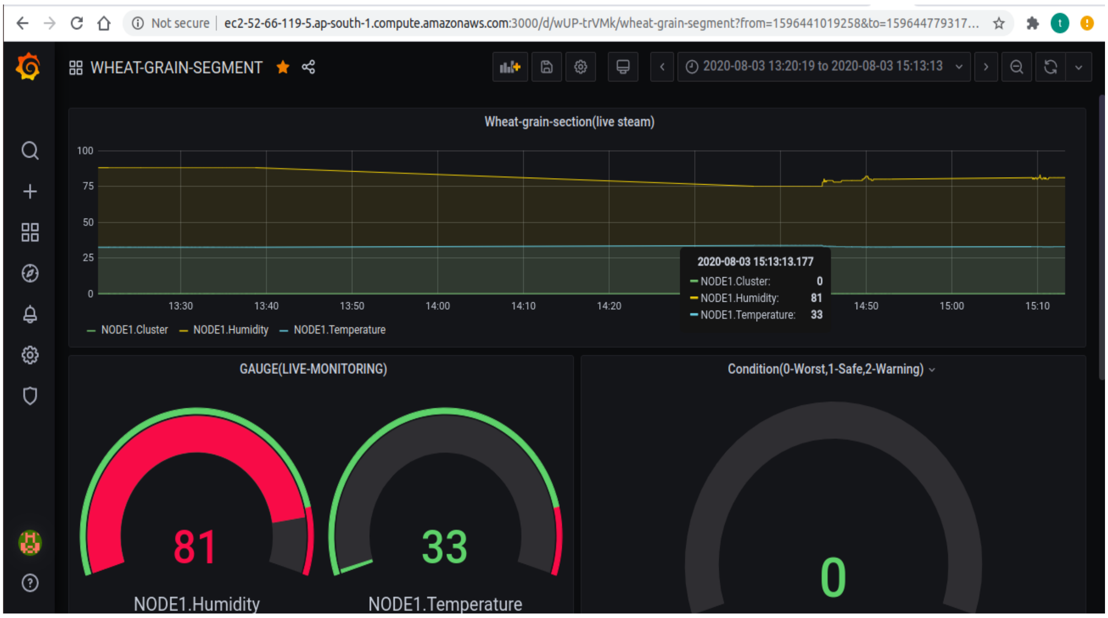

Figure 8. *Grafana Dashboard 1*

Similarly, the Grafana Dashboard showed below in Figure 9 and also showing data readings for Node1 for Rice. Segment Both Temperature and Humidity readings are displayed.

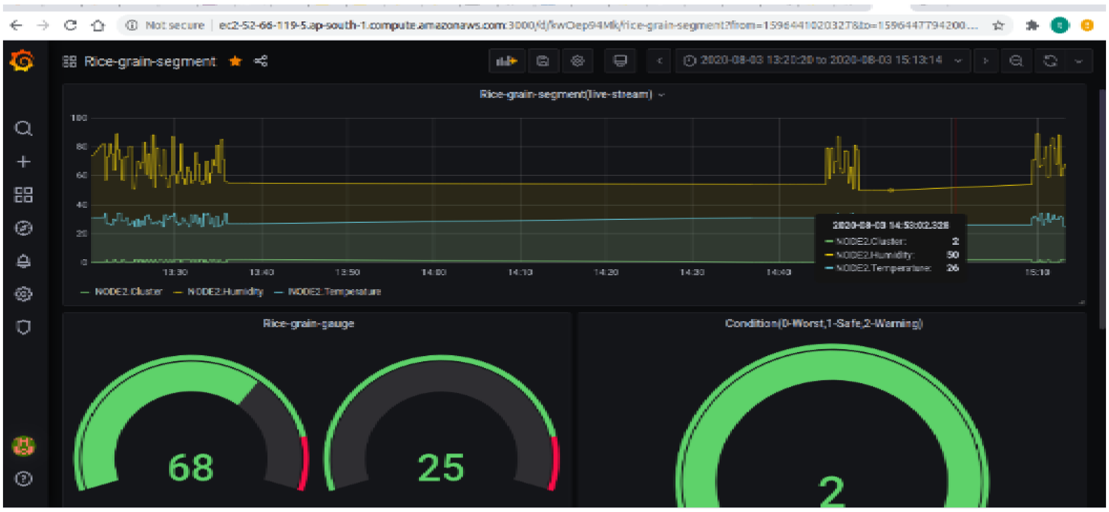

Figure 9. *Grafana Dashboard 2*

5.3. Prophet

Prophet(daily_seasonality=True,weekly_seasonality=False,yearly_seasonality=False

Graph shown below in Figure 10, showing temperature readings and prediction of data based on previously recorded readings using Prophet.

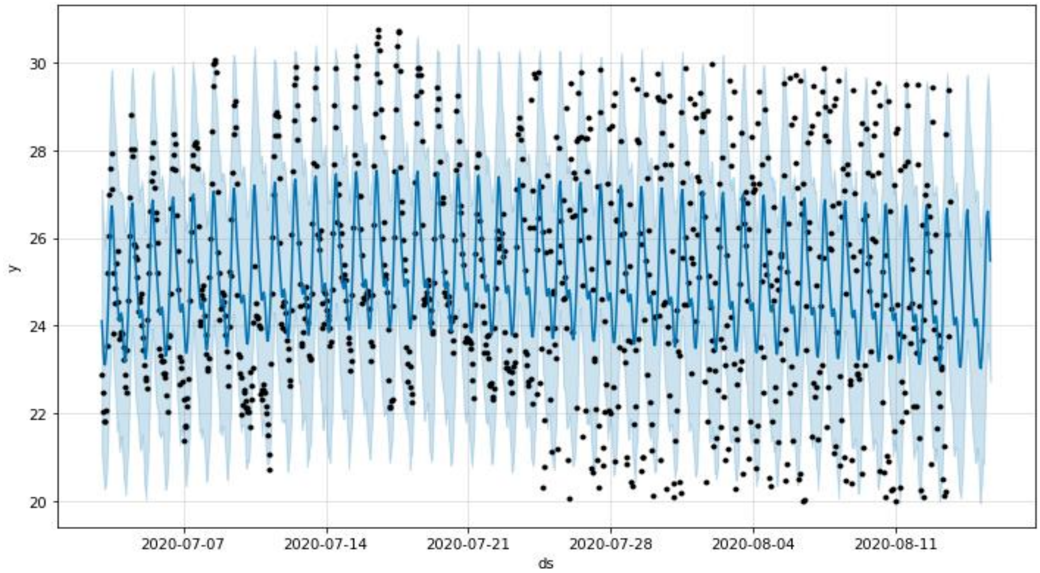

Figure 10. *Prophet Temperature Reading*

Graph shown below in Figure 11, showing humidity readings and prediction of data based on previously recorded readings using Prophet.

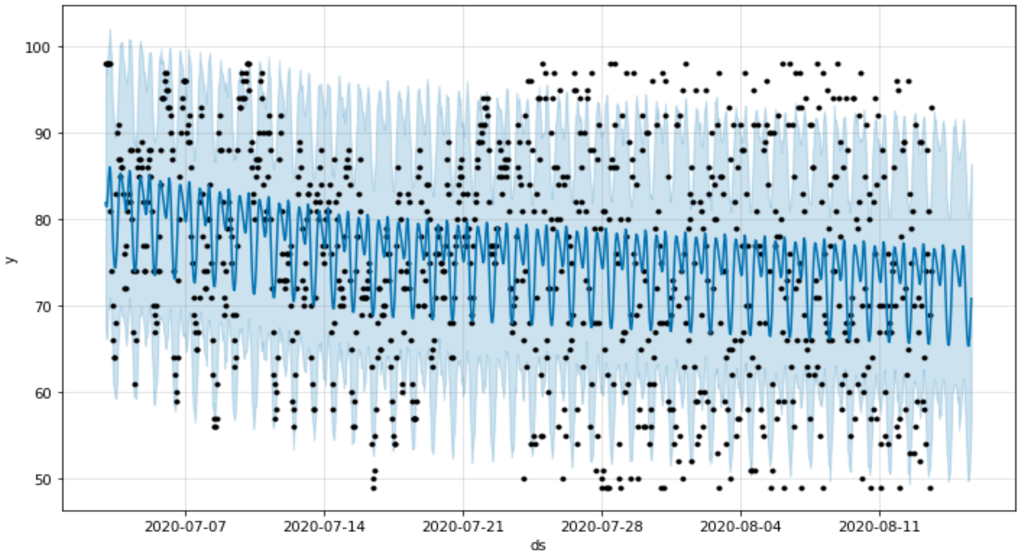

Figure 11. *Prophet Humidity Reading*

5.4. Elbow Method (Finding Optimal Cluster)

Elbow Method Graph showing the optimal number of k that can be used in clustering to get accurate results. The elbow technique is a maximum used in cluster examination to decide the amount of clusters in a data set. Plotting the explained disparity as a task of the number of clusters and selecting the elbow of the curve as the amount of clusters to employ is the method. To find the best possible number of clusters, we must choose the value of k at the "elbow," or the point at which the distortion/inertia begins to reduce in a linear way, as illustrated in Figure 12. Thus, we determine that the best number of clusters for the given data is two. To resolve the optimal number of clusters, we have to pick the value of k at the “elbow. Elbow Method used some important terms these are as follows.

Distortion: It is calculated as the average of the squared distances from the cluster centers of the respective clusters. Typically, the Euclidean distance metric is used.

Inertia: It's the total of samples' squared distances from the cluster centre.

For K-means clustering, the Elbow Technique Visualize uses the "elbow" method of finding the ideal number of clusters. K-means is a straightforward unsupervised machine learning method that divides data into a set of clusters (k). The technique is rather naïve in that it assigns all members to k clusters even if it is not the appropriate k for the dataset since the user must select k in advance.

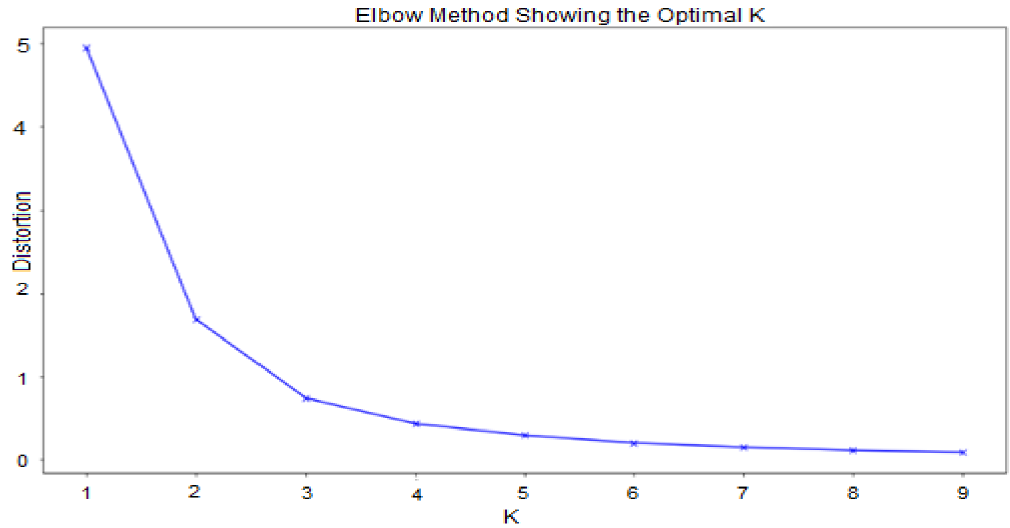

Figure 12. *Elbow Method Graph for Clusters*

5.5. Warehouse Website

A website shown below in Figure 13, which shows the complete details of the goods stored in the warehouse and the optimum conditions used for storing them individually, which makes it easy for the person whosoever is monitoring and for the users too.

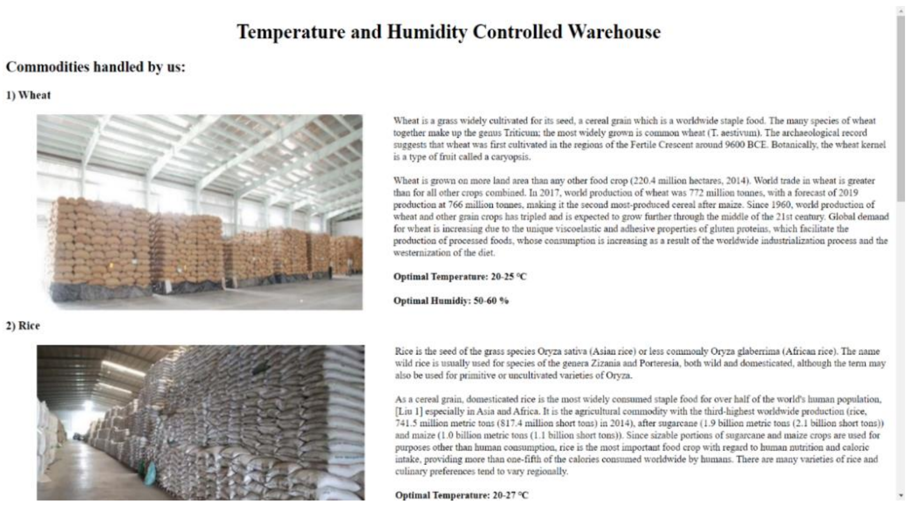

Figure 13. *Details for stored items with their relative temperature and humidity*

5.6. Flask

Flask API shown below in Figure 14, we are displaying condition/data on web browser using local host. The data recording on a particular node in the warehouse is displayed, with NodeId refers to the ID allotted to every node at the warehouse.

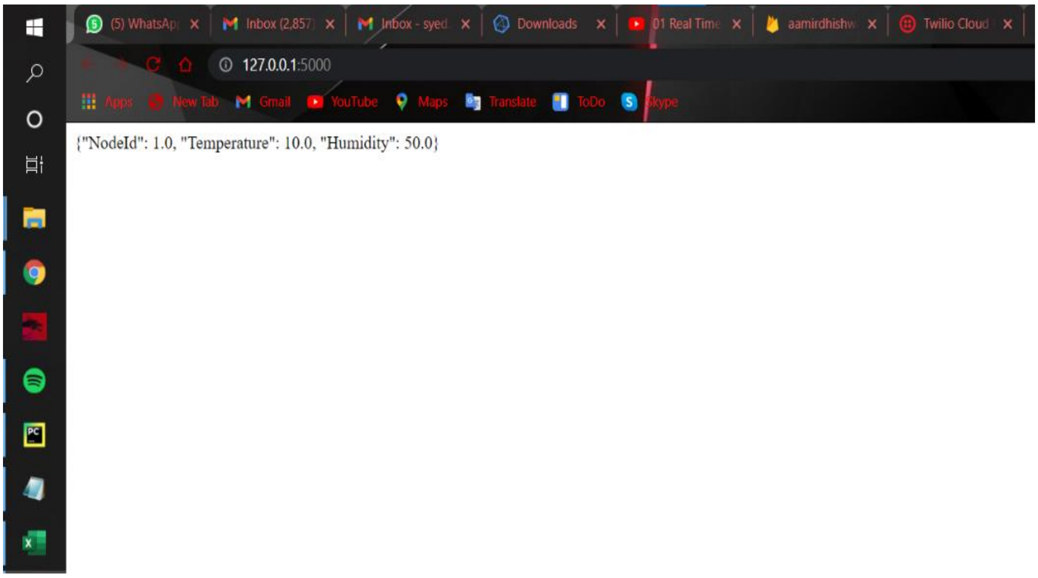

Figure 14. *Using Flask API for visualizing data at each Node located in the Warehouse*

5.7. Twilio

We can also send alert on user’s responsible team E-Mail, as shown below in Figure 15.

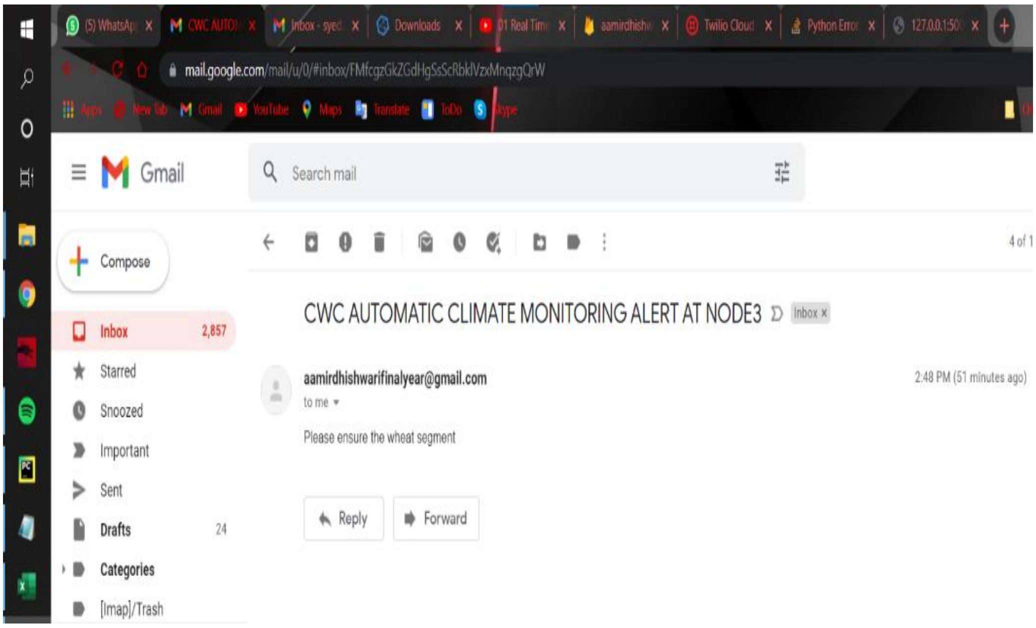

Figure 15. *Using Twilio to send alert on User’s Email*

We can also use message service with Twilio to send alerts to user's/responsible team Phone Number, as shown below in Figure 16, when condition goes inappropriate.

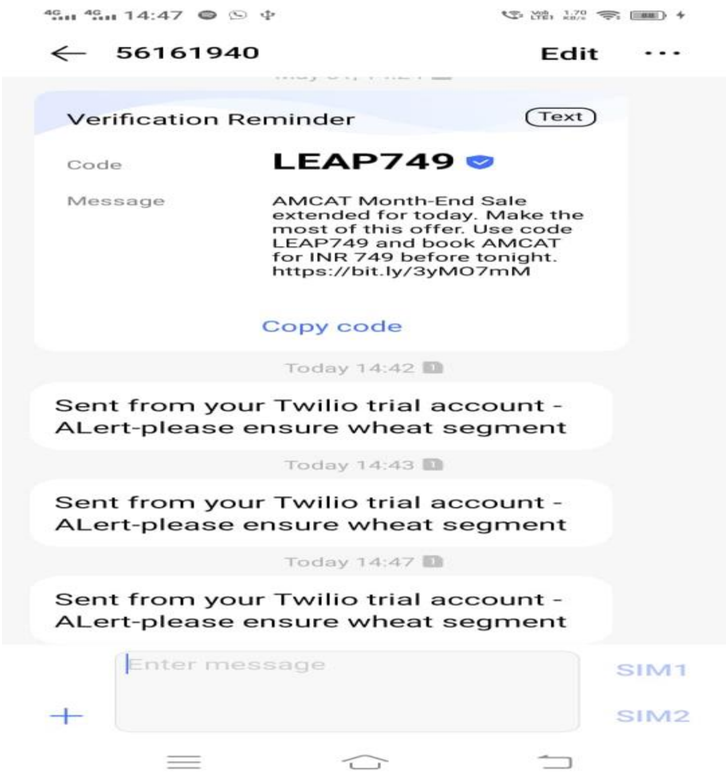

Figure 16. *Using Twilio to send alert on User's Mobile Number*

6. ADVANTAGE OF PROPOSED SCHEME

- Better inform and monitor the impact of regulations to avoid loss of food and grain.
- Data will be accessible from anywhere and anytime.
- Empower farmers to make more informed decisions to increase the profit.
- Reduce the man power for warehouse monitoring.
- Increase the agriculture growth rate of country

7. CONCLUSION

The proposed model has proven to successfully acquire accurate measurements of temperature and humidity. An alarm is sent on to the person in charge or observing person if the value received is above the threshold limit. So, we can easily monitor the items stored in the warehouse and prevents damage to the grains thus maintaining the quality and increasing the life of items stored. The propound method endorse the advancement of the warehouse management system avoiding food waste and unnecessary economic loss. The system is helpful to monitor the various parameters of the warehouse as well. For Future use, one can use Fire or Flame or Smoke detection using Ionization or Photoelectric or Heat, earthquake detection using SES70 and rodent detection and also upload data of warehouse on cloud for future calculation and perdition for loss and profit in term of grain and fruits.

CONFLICT OF INTEREST

No conflict of interest was declared by the author.

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