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Intelligent IoT Based Temperature and Humidity Monitoring System for Tobacco Curing Barn

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Abstract

A Cloud based real time temperature and humidity monitoring device that monitors the tobacco curing process, automates the alarm and notify in case any deviation from prescribed levels of temperature and humidity, transmits temperature and humidity data to the cloud and compare the data against the specified ranges. This system is predicting the future values of temperature and humidity so we can calculate the efficiency of the system. The system tackles the issue of Barn Monitoring System using a low-cost controller. The main idea behind the Intelligent IoT based temperature and humidity monitoring system is to maintain the temperature and humidity inside the barn in each stage of curing. The device has sensor for temperature and humidity. If the humidity crosses the threshold value, it can alert the barn driver and farmer via a Buzzer, SMS, e-mail.

Keywords: Temperature, Humidity, TivaC, Bolt, Tobacco barn

1. Introduction

Curing of tobacco leaves is considered a complex procedure because of the difference in the type of tobacco leaves (moisture content, body etc.) and weather conditions. It is difficult to measure the temperature and humidity level inside tobacco barn in each curing stage. In each curing stage, the color of leaf changes due to heat and it has to be given fix amount of heat in each stage of curing.

There has been a lot of innovation in the field of Tobacco Barn Monitoring System. Temperature and Humidity sensor interfaced with a low-cost controller is a highly-used option. This allows the system to have very low cost. The controller finds out the temperature as well as humidity and sends data to the cloud in every 15 minutes. The advantage of this system is that it can predict future value of temperature and humidity so barn driver can maintain the temperature and humidity according to the requirement. For setting curing stages, manual control has been kept (Kakehi et al., 1986). If the temperature and humidity is above threshold level then it will alert farmer or barn driver via a buzzer, message and e-mail notification.

With the advent of Internet of Things, a more permanent solution to this problem was found. The controller could connect to the internet using GPRS or Wi-Fi and predict the temperature and humidity, thus making smarter decisions.

The objective of this project is to develop an intelligent and affordable IoT based Temperature and Humidity Monitoring System which help the farmer in tobacco curing process. It can show the graph between temperature and humidity with respect to the time on the cloud. Cloud can store the values of temperature and humidity with respect to the time.

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It is to note that that these are reliant upon one another, and will not function proficiently without the other and are discussed below;

A. Hardware

A microcontroller is reading sensor and sending data to the Internet of Things Platform through UART communication (Kakehi et al., 1986). Wi-Fi dongle is used for the internet connection for the proposed system. LCD is used to display the current value of temperature, humidity and status of sensor.

B. Software

Main component in this system is the software which will instruct the hardware as well as process the input from the hardware. It may be a python script or a C program and JavaScript depending on the application.

Temperature and Humidity measurement is important task for the tobacco curing process. It aims at creating and organizing data in a computer based system. Software developed in cross platform language can help the system to work at any remote location with the help of cloud. Most of the development of system is based on the cloud.

The information is obtained from hardware after appropriate processing using software. It is the actual information that is required for the tobacco curing process and for farmer to be ready for the action when barn requires change in temperature according to the need.

C. Procedures

As mentioned earlier measurement of temperature and humidity is very important task of the tobacco curing process. Procedures here refer to the way that software, hardware as well as people interact with the cloud. Artificial intelligence is an important feature of the system which is predicting the temperature and humidity value (El-Henawy et al., 2016).

D. People

People are the main components other than hardware which play important role in maintain the temperature level inside tobacco barn. Here one has to take care of the system and check predicted value of temperature and humidity at regular interval of time.

The basic objective of this system is to measure temperature and humidity value inside barn and send notification to the barn driver when it is other than the threshold limit. Prediction of temperature and humidity value is used to take action in advance when tobacco leaves have higher temperature during curing process.

E. Challenges in Tobacco curing

In manual measurement of temperature and humidity inside tobacco barn, farmers need to check temperature inside tobacco barn manually (Tobacco-curing barn (1926). Currently, many farmers uses their experience and guesswork to monitor the temperature and humidity inside the barn. The farmer touches the barn walls or put hand inside the barn to sense the temperature level. It is not possible to enter in barn in third and fourth stage due to high temperature inside the barn. After manual measurement, they can change the temperature inside tobacco barn. In third and fourth stage, farmer cannot check temperature because of high level of temperature inside tobacco barn.

2. Motivation

There is no automatic machine for measuring the temperature and humidity level inside barn. As mentioned earlier, many farmers use their experience and guesswork to monitor the temperature and humidity inside the barn. The farmers touch the barn walls or put hand inside the barn to sense the temperature level. It is not possible to enter in barn in third and fourth stage due to high temperature inside the barn.

The temperature of barn varies from 85 degree Fahrenheit to 160 degree Fahrenheit and the humidity varies from 15% - 90%. Barn driver has to check temperature of barn from leaves color if it is getting more yellowish then he has to decrease temperature (Kakehi et al., 1986). This method requires more man power. One person should be always near to barn and check the temperature and humidity level at regular interval of time. If the humidity is not maintained properly then tobacco may lose the moisture content and it will cause poor quality of tobacco leaves. Similarly, temperature is not maintained properly then it will affect the quality of tobacco leaves. So, it is necessary to maintain the proper temperature and humidity during curing stages of tobacco leaves to meet consumer requirement.

3. Literature Survey

The "tobacco barn" is a storage house for the tobacco leaves during the curing process. The design of tobacco barn includes frame construction, roofs and ventilation so that it can be open from the outside. The ventilation is important for the efficiency of the tobacco barn. Farmers can open these ventilations and hang tobacco leaves and can check leaf colour after every stage of curing (Tobacco-curing barn 1926). The ventilation is also useful for the chemical breakdown during curing process, because of ventilation leaf changes its colour in every stage of curing that is green to yellow to brown.

The curing of tobacco is a controlled drying process. When a tobacco leaf is taken from the plant, it contains 80-90% moisture and 10-20% solids by weight. The environment condition in which tobacco leaves is growing also affects the range of temperature and humidity in different stages of tobacco curing. The design of tobacco barn also affects the curing process of tobacco barn.

3.1 Manual Measurement of Temperature and Humidity

In manual measurement of temperature and humidity inside tobacco barn, farmers need to check temperature inside tobacco barn manually. Currently, many farmers use their experience and guesswork to monitor the temperature and humidity inside the barn. The farmer touches the barn walls or put hand inside the barn to sense the temperature level. It is not possible to enter in barn in third and fourth stage due to high temperature inside the barn (Tobacco-curing barn 1926). After manual measurement, they can change the temperature inside tobacco barn. In third and fourth stage, farmer cannot check temperature because of high level of temperature inside tobacco barn.

The above described practice is not a good method for curing the tobacco leaves. For efficient and safe curing of tobacco leaves, the temperature and humidity level should be maintaining inside the tobacco barn. Barn driver has to check temperature of barn from leaves color if it is getting more yellowish then he has to decrease temperature. This method requires more man power. One person should be always near to barn and check the temperature and humidity level at regular interval of time. If the humidity is not maintained properly then tobacco may lose the moisture content and it will cause poor quality of tobacco leaves. Similarly, temperature is not maintained properly then it will affect the quality of tobacco leaves. So, it is necessary to maintain the proper temperature and humidity during curing stages of tobacco leaves to meet consumer requirement.

3.2 Dry and Wet Bulb Method

The wet-bulb thermometer (Hasan, 2010) is used for the measurement of the temperature of the leaf during early stage of curing and the dry-bulb thermometer is used for the measurement for the air temperature. Most of the farmers uses wet-bulb thermometer to measure air temperature. The humidity level is also important for the curing process. The humidity and the dry-bulb temperature must be controlled during curing process; wet-bulb thermometer indicates when the necessary adjustment needed in the ventilation in the barn. For the good observation, place the dry-bulb thermometer under the tobacco so no need to open the door of tobacco barn and place the wet-bulb thermometer between racks or on the top of tobacco to get accurate reading from the wet-bulb thermometer.

Humidity level inside barn can be controlled by the adjustment in the fresh air exchange rate with the ventilation system. The relationship between the dry-bulb thermometer and wet-bulb thermometer determines the relative humidity within the tobacco barn.

3.3 Notifications

As discussed above, based on the results of the analysis, concerned authority is notified. Notification can be made via an electronic mail or an automated voice call or by buzzer. This eliminates the need to keep monitoring the system or reduces the overhead of barn driver.

4. Methodology

The flow is illustrated in the Fig. 1 and is discussed briefly in this section. Methodology includes four main sections – Read Input and Send to Internet of Things Platform, Data visualization and prediction [6]. The method discussed in the above section is implemented as shown in the fig. 3 Artificial Intelligence is implanted on the Internet of things Platform.

4.1 Read Input

The sensors are connected to master controller unit via a high-temperature wire or wirelessly. The sensors are either connected to the edge of the barn or equally in the barn or placed at a strategic location to get the most optimum data. The position of the temperature and humidity sensors has been chosen as in the Centre of the barn. This is done by using high-quality wires that can withstand high temperature environments. The master controller unit has an LCD display with 16*4 display to show the current temperature and humidity and also status of the sensors.

4.2 Send data to the Internet of Things Platform

The system is also sending all the data to the cloud via a GSM network. From the cloud, the data can be displayed over an app on a smart phone (Kakehi et al., 1986). The system is connected with the GSM module that connects the device to the cloud over the internet. The system also consists of Wi-Fi module which can be used in place of GSM to do same task of connecting the device to the cloud via the internet.

4.3 Data Visualization

The system also continuously logs the data on the cloud. The data collected is automatically visualized in form of line graph to show variation over time. There is also a gauge to show the current values of the sensor data. The cloud has an onboard analytics platform which can run various types of analysis like correlation, regression etc. to get actionable insights from the data (Chen et al., 2007).

During the curing process, the temperature threshold is different for each stage. The farmer manually rotates the knob on the barn monitor to indicate the change in the stage. The threshold for the alert change based upon the stage.

4.4 Artificial Intelligence

A decision tree is an unsupervised learning algorithm. It is a tree like structure which includes a root node, branches and leaf nodes (El-Henawy et al., 2016). The decision tree algorithm generates a model that is able to find out the sets in every condition of tobacco barn.

Confusion matrix is a table which is used to describe the performance of a classification model (Lewis, & Brown, 2001). This uses a set of data for which the true values are known. There are two possible prediction classes: “yes” and “no”. If one is predicting the presence of a true value of label, for example, “yes” means the value of Temperature or Humidity is true and “no” means the value of Temperature or Humidity is not true.

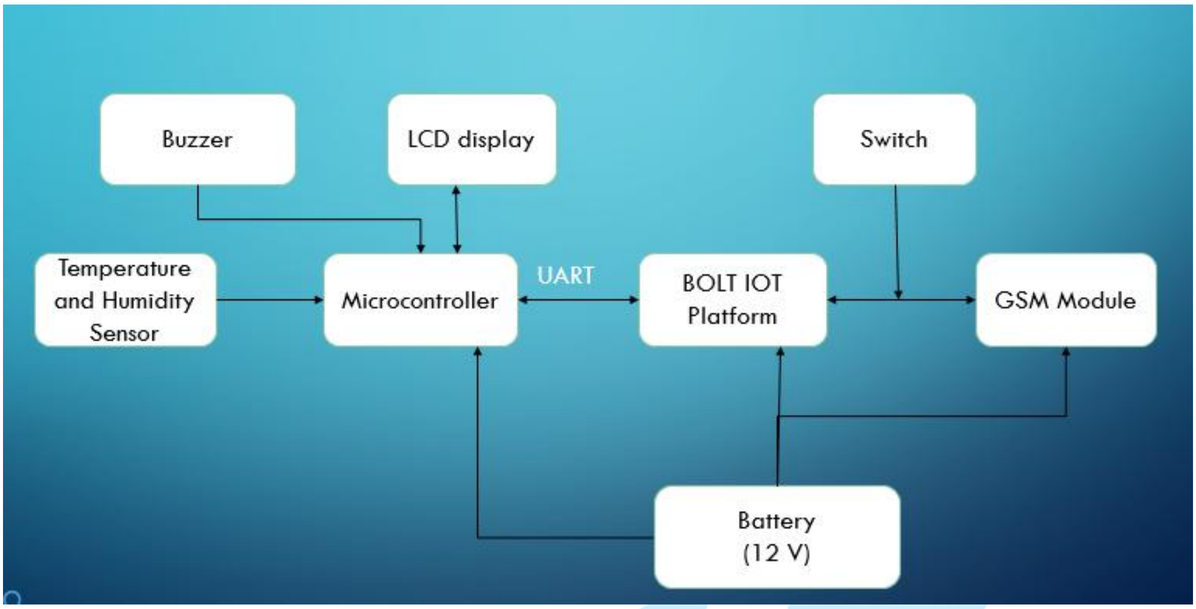

Fig. 1 Block Diagram of System

The basic terms used in confusion matrix are –

- TN (True Negative): when predicted “no” and in actual it is not present.
- FP (False Positive): when predicted “yes” but in actual it is not present.
- FN (False Negative): when predicted “no” and in actual it is present.
- TP (True Positive): when predicted “yes” and in actual it is present.

5. Experimental Results

As per the proposed system, one is able to measure temperature and humidity. Fig. 2 and Fig. 3 show the graphs between temperature and humidity v/s time.

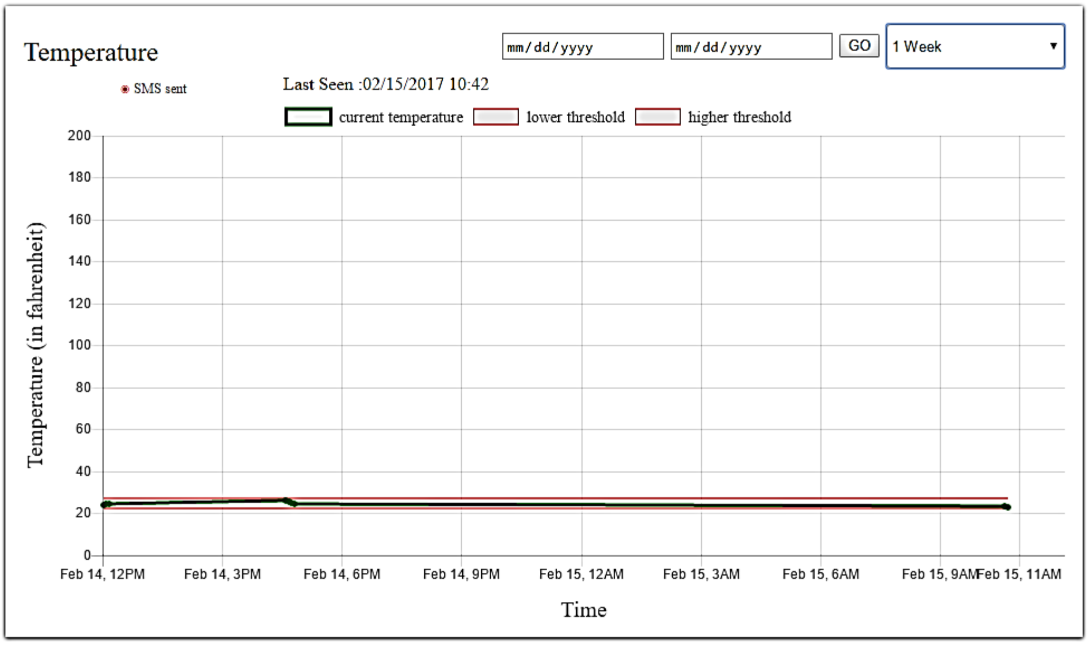

Fig. 2 Graph of temperature v/s time

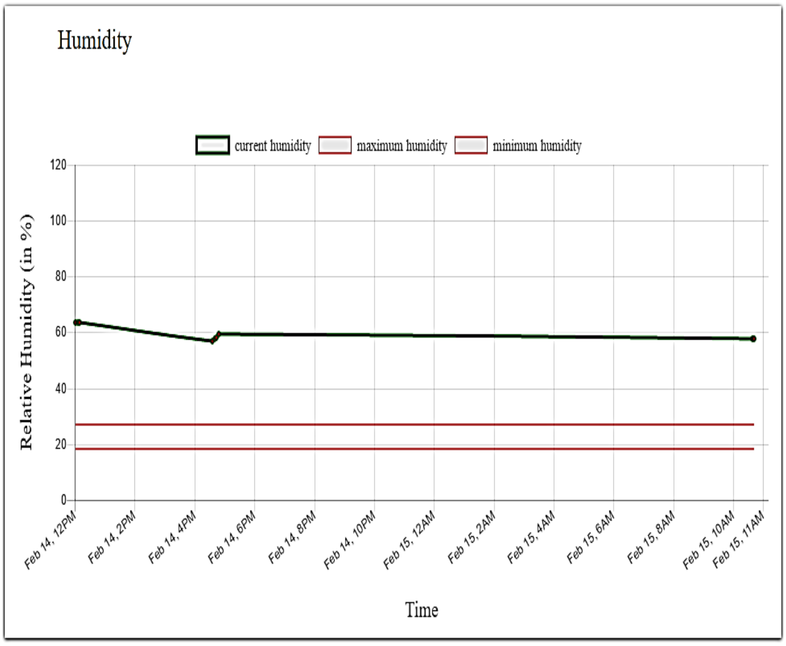

Fig. 3 Graph of humidity v/s time

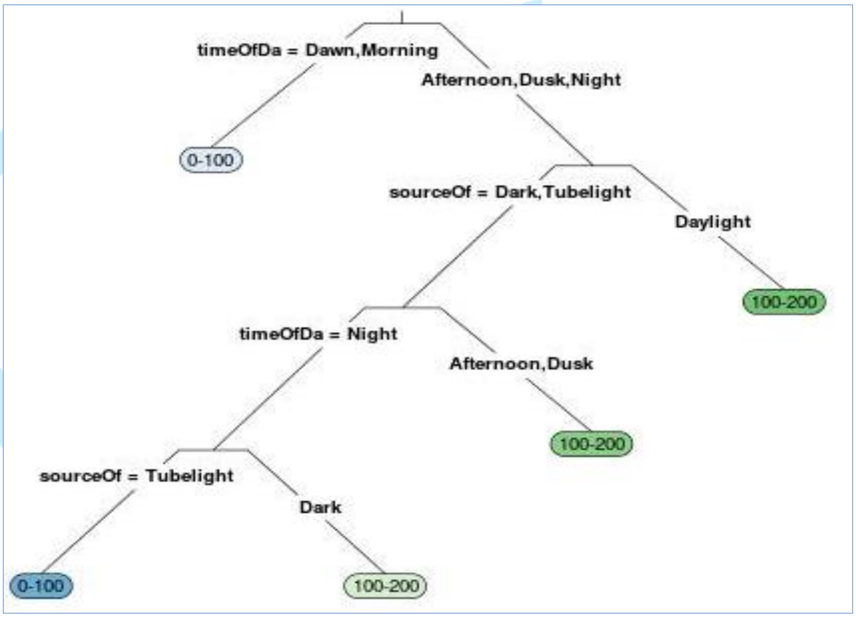

Fig. 4 Training model of dataset

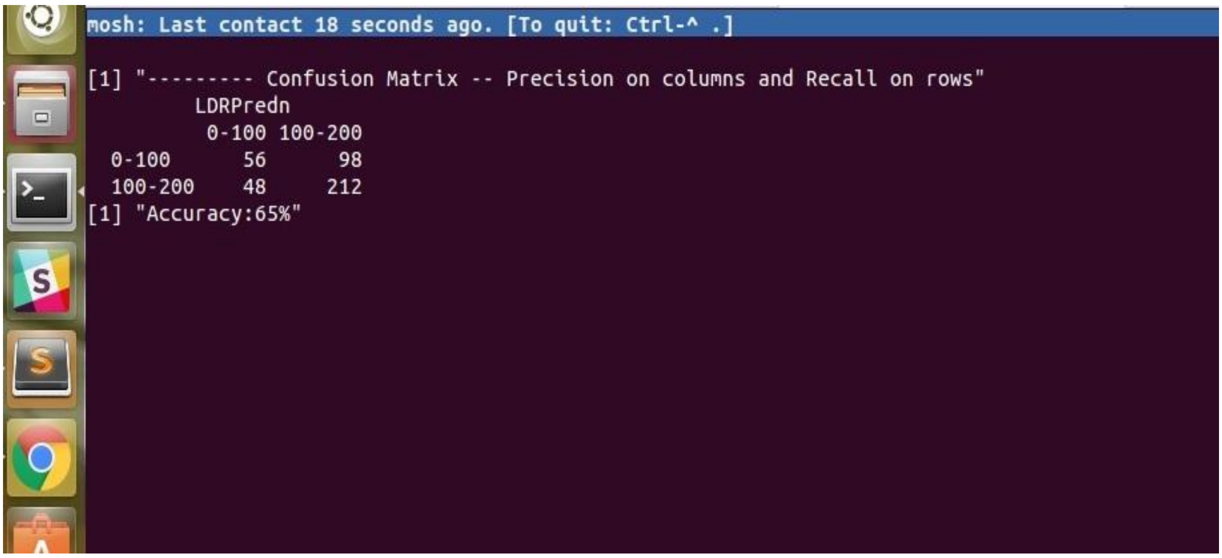

Fig. 5 Confusion matrix of training data

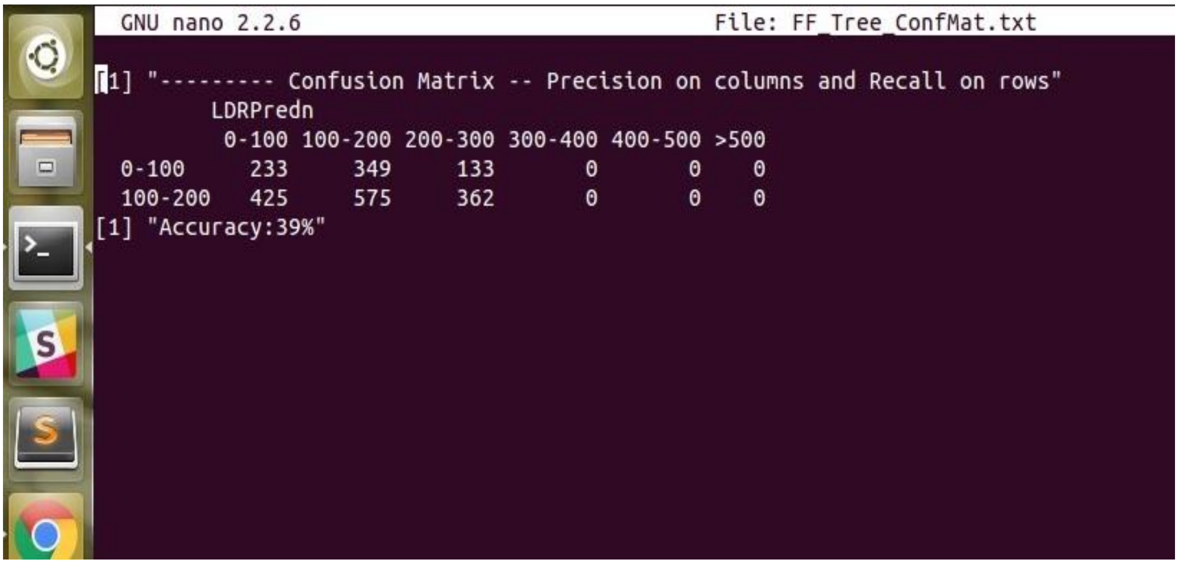

Fig. 6 Confusion matrix of prediction data

The measured temperature and humidity values are sent every 15 minutes to the Bolt cloud. Graph is able to show previous values which are useful for the analytics. It can store the values of sensor in the data storage so you can download data in the future. Fig. 4 is a training model which generated after training of data. It is useful for understanding that how model is going to predict that data of temperature and humidity.

Fig. 5 is a confusion matrix of training dataset. The classifier made a total of 414 predictions that is 414 data point was tested for the true value of prediction of Temperature and Humidity values (Lewis, H. G., & Brown, M. 2001). The values in raw tells that out of total of 154 labels of 0-100, the algorithm correctly recalled 56 while at column's, it says that out of 104 prediction of 0-100, it got 56 correct values. The values in raw tells that out of total of 260 labels of 100-200, the algorithm correctly recalled 212 while at column's, it says that out of 310 prediction of 100-200, it got 212 correct values.

Fig. 6 is a confusion matrix of prediction dataset. The values in raw tells that out of total of 715 labels of 0-100, the algorithm correctly recalled 233 while at column's, it says that out of 658 prediction of 0-100, it got 233 correct values. The values in raw tells that out of total of 1362 labels of 100-200, the algorithm correctly recalled 575 while at column's, it says that out of 924 prediction of 100-200, it got 575 correct values. The labels in 200-300 are all wrong prediction.

Fig. 7 is a final output of the prediction of temperature and humidity in CSV format. The F column is representing the Temperature band and G column is the prediction band of temperature. Temperature band is between 0-100 and temperature prediction band is also showing the band of 0-100. Both bands are equal that means the prediction values of temperature are correct.

	A	B	C	D	E	F	G	H	I	J
1		timeOfDa	locationIn	sourceOfL	roomNam	TempBan(	tempPredn			
2	510	Night	North	Dark	Tobacco B	0-100	0-100			
3	511	Night	North	Dark	Tobacco B	0-100	0-100			
4	512	Night	North	Dark	Tobacco B	0-100	0-100			
5	513	Night	North	Dark	Tobacco B	0-100	0-100			
6	514	Night	North	Dark	Tobacco B	0-100	0-100			
7	515	Night	North	Dark	Tobacco B	0-100	0-100			
8	516	Night	North	Dark	Tobacco B	0-100	0-100			
9	517	Night	North	Dark	Tobacco B	0-100	0-100			
10	518	Night	North	Dark	Tobacco B	0-100	0-100			
11	519	Night	North	Dark	Tobacco B	0-100	0-100			
12	520	Night	North	Dark	Tobacco B	0-100	0-100			
13	521	Night	North	Dark	Tobacco B	0-100	0-100			
14	522	Night	North	Dark	Tobacco B	0-100	0-100			
15	523	Night	North	Dark	Tobacco B	0-100	0-100			
16	524	Night	North	Dark	Tobacco B	0-100	0-100			
17	525	Night	North	Dark	Tobacco B	0-100	0-100			
18	526	Night	North	Dark	Tobacco B	0-100	0-100			
19	527	Night	North	Dark	Tobacco B	0-100	0-100			
20	528	Night	North	Dark	Tobacco B	0-100	0-100			
21	529	Night	North	Dark	Tobacco B	0-100	0-100			
22	530	Night	North	Dark	Tobacco B	0-100	0-100			

Fig. 7 Final prediction of data in CSV format

6. Conclusion

The advances in Wi-Fi hardware modules enable Internet connectivity at affordable costs; the cost of an Internet of Things platform is also affordable. This helped in the successful deployment of the proposed temperature and humidity monitoring system with intelligent features at affordable cost for the tobacco barns. The sensor provides real time temperature and humidity values, making the system smart. The incorporation of Artificial Intelligence makes the system really intelligent. The system can think and take decision according to the values got from the temperature and humidity sensor.

The prediction of temperature and humidity is not that much effective. The accuracy of prediction is around 35 – 40%. With more iteration in the algorithm, one can increase the accuracy of the prediction. Now, the band size is 0-100 that means the limit is quite big so we can reduce the band gap to small band such as 0-10, 10-20 etc. If band gap is less than chances of predicting the exact value is high. But it needs more iteration while programming the algorithm leading to lesser response time and more computational time. The accuracy of prediction can also be increase by the more number of training dataset. For any prediction, the training of data is very important. If the system is trained with more number of data then it can give more accuracy.

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Declaration of Conflict

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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