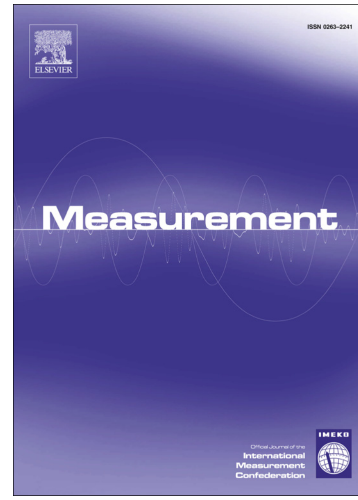

CLAY-MIST: IoT-Cloud Enabled CMM index for Smart Agriculture Monitoring System

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PII: S0263-2241(18)31009-1
DOI: https://doi.org/10.1016/j.measurement.2018.10.072
Reference: MEASUR 6012

To appear in: *Measurement*

CLAY-MIST: IoT-Cloud Enabled CMM index for Smart Agriculture Monitoring System

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Abstract

The temperature and soil moisture factors affect the growth of agriculture such as productivity, diseases, and yield production. Most of the existing techniques were used to assess comfort level based on dew-point-humidity data which gives a false decision with time and energy consumption. To comprehend these issues, we proposed a cloud-enabled CLAY-MIST measurement (CMM) index based on temperature and relative humidity to assess the comfort levels of a crop. In this research, temperature quotient is evaluated based on the amount of water vapour and pressure in the air which appraises plant growth. The relative humidity is subtracted with the standard constant optimal temperature to extract the comfort level. Therefore, the CMM index experiments with real-time data show an accurate decision and the detailed report sent to farmers. The results are 94% accurate with less execution time when compared with the existing thermal comfort techniques.

Keywords: Internet of Things, Cloud Computing, CLAY-MIST measurement index, Agriculture monitoring system.

1. Introduction

Internet of Things (IoT) is creating a new era for IT computation fields. IoT defines all daily human life objects, things, and devices are connected and communicated with each other through an internet connection [1]. IoT has encroached groundbreaking solution to various sectors like civilization, transportation, healthcare, home automation, agriculture, industry and environment. IoT has intruded itself deeply into these fields. IoT aims to connect every person and every object through an internet. The security can be achieved based on a unique identification number is known as IP address. It is used to communicate over IoT devices [2]. In today's world, around 5 billion objects have connected through the internet. In 2020, it has estimated that nearly 50 billion objects will connect to the internet. However, by replacing smart agriculture technologies instead of traditional agriculture methods can able to get high production yield to manage the problems [3]. A huge loss occurs in agriculture due to the following factors:

- Delayed sowing and poor seed quality.
- Environmental hazards.
- Insect and disease attacks.
- Unplanned irrigation and water losses.
- Misuse of fertilizer and insecticides.

1.1. IoT impact on traditional agriculture system

In the last decade, technological changes also affected agricultural crop production. With the help of sensor devices, farmers can remotely know about their field information like saturated soil temperature [4], soil moisture [5], an occurrence of plant diseases and pests in plants [6]. Farmers react timely manner to preserve crop loss based on received information. The IoT farmers can get high production yield based on smart agriculture methods [7].

1.2. Measurement impact on smart agriculture system

The traditional agriculture methods didn't extract an optimal range of production yield. Because, there is no proper measurement to predict the utilization of natural resources like water, fertilizers, temperature, soil moisture and nutrients. If anyone of this resource lacked, then the crop get related diseases which lead to less production yield. To overcome this type of issues we proposed a new measurement function which is used to measure the growth of the crop, crop comfort levels and these are the input parameters to make a successful smart agriculture monitoring system. The optimal temperature and relative humidity values must be calculated to extract the above

*P Viswanathan

parameters. This process is carried out with our new proposed CLAY-MIST measurement index function.

IoT cloud. [8] is used to store sensor data and assessing this sensor data to make a decision is an important task to get an appropriate result. Table 1 shows IoT based cloud servers list with free and pay per use types. In our proposed work www.thnigspeck.com is used for execution. It is free of cost and associated with the mat lab application server to perform data analysis with graphical representation. Cloud-IoT plate forms [9, 10] plays a vital role in IoT for storing data which is collected from sensors [11] and cameras. The important function of the decision-making system is finding out faults and crop diseases based on the analysis of sensed data. This information is sent to farmers to get action according to the decision.

1.3. Motivation

IoT is one of the emerging technology throughout the world in human lifestyle. Under that thermal comfort is an important measurement and it can be done practically with pen-paper and real implementations [12]. From the past three decades, more loss in agricultural yield production because changes in the environment due to global warming and greenery damaged hazards. To overcome this issue, measuring temperature, soil moisture and relative humidity values in a periodical manner and take a necessary action to prevent this loss. Thermal comfort estimation is an existing plan in such circumstances. The thermal comfort [13] is controlled by measuring some parameters like air temperature, air flow, relative humidity.

The remainder of the paper organized as follows. Section 2 provides related works done so far in this field. Section 3 Proposed model, Section 4 Experimental setup of a physical model, Section 5 Result analysis and, Section 6 is deriving the conclusion.

2. Related work

IoT is used in many domains such as precision system [14], management of supply chain products [15], smart grid management system, monitoring smart environmental system [16] to decrease utilization of power and increase performance. Past few investigations demonstrated that applications are created to quantify natural and different parameters using IoT.

In [17], the author proposed MISSENARD index thermal comfort measurement function based on temperature (P) and humidity(H) defined in Eq. (1). It is suitable for human thermal comfort for indoor occupants. It represents maximum comfort level even at high temperature and generates error results during abnormal conditions when multiplied with a standard value. There is no proper method to assess crop development. The proposed measurement algorithm solves these issues.

$$ET = P - 0.4 * (P - 10)(1 - H/100) \quad (1)$$

In [18] Humiture Index (Winterling 1979, see Enache, 2001) has proposed a measurement function for finding discomfort level defined in Eq. (2). In this work, it has used temperature and dew point (d) parameters to evaluate the thermal humidity (TH). This concept lacks to give an optimal value to the farmers to take necessary action towards healthy growth. It will not generate accurate results due to the utilization of dew point 'd' whereas CLAY-MIST measurement index gives accurate results. All the notifications about agriculture field sent to the farmers.

$$TH = P + (d - 18) \;\forall\; P \;<\; 30°C, \quad (2)$$

In [19] Humidex index, the author proposed a monitoring framework for extracting comfort and discomfort levels. The creators explained the utilization of temperature and dew point based on water vapour pressure in the air (e) defined in Eq. (3). Due to the dew point parameter (e), resulting values are not appropriate. To solve this issue proposed work used relative humidity for better results. The developer has not given clear idea about thermal comfort to make a better decision. The CLAY-MIST measurement index uses relative humidity to get accurate results.

$$H = P + 0.5555(e - 10) \quad (3)$$

In [20] UTCI describes weather, climates and location changes much better. Therefore, UTCI is extremely delicate to measure the changes in solar radiation−73.5°C to 45.6°C, wind speed (v_{10}) from 0.514 ms^{-1} to 30 ms^{-1}, air vapor pressure (vp) from 0 hPa to 42.56 hPa. Mean radiant temperature (Tmrt) changed from −93.6°C to 78.9°C. The difference between Tmrt and T was within the range of −19.0°C to 56.0°C. These measurements are not accurate due to the consideration and combination of wind speed instead of relative humidity.

In [21] the apparent temperature (AT) index is determined as the temperature (T) proportionally depends on the respective humidity level results in an equal amount of discomfort. Fundamentally, AT is an adaptation of the temperature based on the amount of humidity level defined in Eq. (4). Absolute humidity including a dewpoint 16.0°C taken as a base source (reference). If moisture (humidity) is greater than the source (reference), then AT will be greater than T; if moisture (humidity) is relatively less than the source (reference), then AT (AT<T) will be less than T. The amount of variation is managed by the assuming with Steadman model. It is efficient over an extended range of temperatures with moisture, but due to the utilization of dewpoint (vp) and chilling effect (v) during lower temperatures not able to measure accurate values.

$$AT = T + 0.33 \cdot vp - 0.7 \cdot v - 0.4 \quad (4)$$

In [22] wind chill index WCI(Wm^{-2}) developed to estimate the wind cooling power defined in Eq. (5). It evaluates the impact of wind on cold environments in winter

IoT Platforms	*Cloud service type*	*Data analytic s*	*Developer cost*
Ubodots(http://ubidots.com/)	Public	Yes	Free
ThingSpeak (https://thingspeak.com/)	(Mat lab)Public	Yes	Free
ThingWorx (www:thingworx.com/)	Private (IaaS)	Yes	Pay per use
Xively (https://xively.com/)	Public (IoTaaS)	No	Free
Plotly (https://plot.ly/)	(Mat lab) Public	Yes	Free

Table 1: most of the IOT cloud platforms used for agricultural domains.

seasons. In North America, the WCI is used to predict imperative winter weather. It is suitable for winter season because it is unable to measure in abnormal conditions.

$$WCT = 13.12 + 0.6215 \cdot T - 11.37 \cdot v_{10}^{0.16} + 0.3965 \cdot T \cdot v_{10}^{0.16} \quad (5)$$

where v_{10} refer as wind speed (in m^{-1}) at 15 m higher of the surface level. The WCI-related level of hazards defined in Table 2.

In [23, 24], the author proposed an application based on IoT for animal stock chain management. The RFID technology is used to track or monitor animal behavior. The author proposed a framework to determine the rice plant's illness [25]. The initial step is information acquisition. The second step is the determination of illness in the leaves of the crop. Hence, There is no such model to find out the cell growth and comfort level of agriculture crop. In our proposed framework, we use relative humidity to solve this issue. The initial steps make information better based on condition rules. Therefore, CLAY-MIST measurement index is used to overcome the difficulties of the parameters in the existing system for continuous monitoring methods.

3. Determination process of proposed model

Temperature is important because plant growth requires energy through the process of photosynthesis. i.e leaves of trees and shrubs capture light energy from the sun and convert it to soluble carbohydrates (starch and sugar). These soluble carbohydrates are distributed to all parts of the plant to satisfy energy for growth. The leaves of different plants differ in capturing the sun energy. The shade-tolerant trees like dogwood, redbud, beech, linden consumed the available subdued or filtered light energy.

the livestock weather safety index (LWSI)categories represent the information of water because an adequate amount of water is essential for plant growth and maintenance of the plant process. An organic process doesn't occur in the absence of water. But plants probably suffer more from moisture-related problems. Either lacking or an excess of water is the main reason for the death of recently planted trees and shrubs. The issue of excess water is increased in turf-grass and woody plants because it requires more water to maintain. In many seasons, every 7 to 10 days around 1 inch of water is required to grow tree and shrub.

3.1. Agriculture CLAY-MIST index measurement IoT cloud model

Fig 1 shows 5-layers architecture. In this architecture, the conceptual layer has microcontroller board to receive data from the physical layer which consist of sensors to monitor agriculture field. It also evaluates the plant growth. The microcontroller manipulates the CLAY-MIST measurement index based on data received from the humidity and temperature sensors deployed in the physical layer. The file information along with temperature (P) and relative humidity(Q) are evaluated based on relative water vapor (RWV) in air using Eq. (6). The amount of temperature f(x) with constant variables $a = 1.6$, and $b = 30$ and g(x) are evaluated using Eq. (7) and Eq. (8). Those equations are used to calculate soil condition and water requirement through CLAY-MIST measurement index. This layer plays a vital role in calculating CLAY-MIST measurement process. These results are sent to farmers through message notifications as SMS or Mail alerts.

$$RWV = 1 - (Q/100) \quad (6)$$

$$f(x) = P \times a + b \quad (7)$$

$$g(x) = f(x) - 58 \quad (8)$$

The application layer is the client interaction layer intended to follow the required parameters like graphical perception, observing a current situation, and measured values in a complete mechanized way and these are used to monitor the agriculture crop field.
Fig 2 shows agriculture IoT model with new adopted measurement function and execution process. The serial monitoring system is used to monitor decision making of Thingspeck cloud based on calculated values. The relative humidity is used to find out the presence of water in the air is used to take an optimal decision by an agriculture crop monitoring system. The soil sensors gather information about soil condition, soil moisture and soil nutrients. The climate sensors gather information of humidity and temperature. The server analyzes, chooses the disease from

Table 2: WCT-related level of hazards

S.No	WCT(°C)	Type of level	Respective impact
1	0 to -9	Low	Slight discomfort
2	-10 to -27	Low	Uncomfortable
3	-28 to -39	Risk	Risk of skin can freeze in 10 to 30 mins
4	-40 to -54	High risk	Exposed skin can freeze in 2 to 16 mins
5	-55 and colder	Extremely high risk	DANGER!: Exposed skin can freeze in less than 2 mins

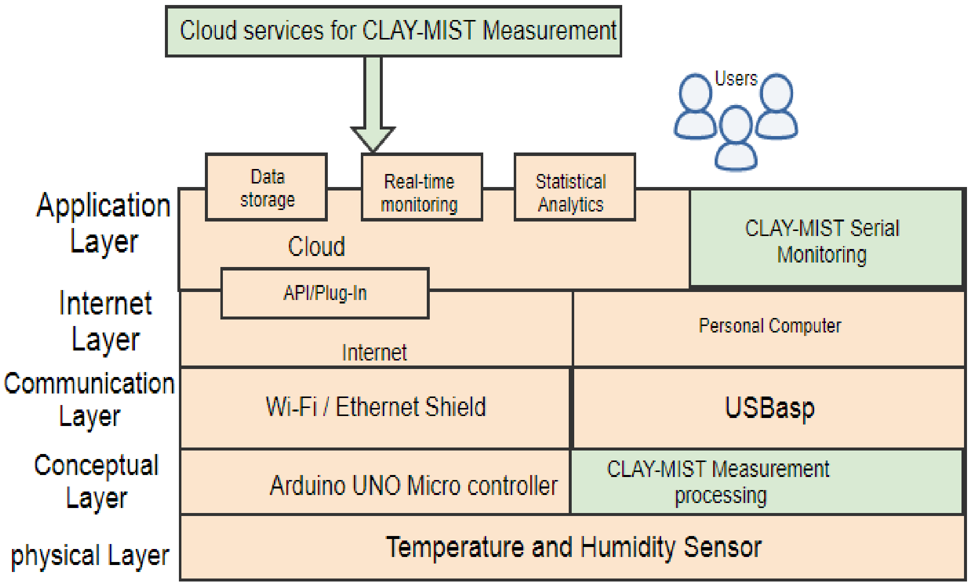

Figure 1: Agriculture IoT-cloud based CLAY-MIST measurement index layered architecture

the real list based on data received from sensors which are utilized to take appropriate action. On the server side, the master framework which frames and separates the information based on the prescribed threshold list and sent the analyzed proposal to the farmer about crop yields.

3.2. Temperature quotient (PQ_{10})

Cell growth classified into two components: cell division and cell enlargement. The cell division and cell enlargement of radical tip require optimal temperature 25°C and 30°C respectively. The elongation of radical is optimized at 30°C, indicating that cell enlargement dominates the division. The elongation of radical stops below 15°C and above 40°C. The temperature quotient (PQ_{10}) is used to assess the effect of temperature on the growth rate and differentiation defined in Eq. (9).

$$PQ_{10} = \frac{Rate\ at\ (P + 10)}{Rate\ at\ (P \times 2.5)} \tag{9}$$

Where
P refers temperature.
PQ_{10} value is in between or closed to i and j constant variables.

The temperature during seedling growth is very sensitive in the first week of postgermination. The growth rate increases linearly from 22 and 31°C, indicating that chemical reactions dominate the growth. A temperature 22°C or below is considered as normal for seedling growth. The seedling growth reasonably good up to 35°C and seedlings will die above 40°C. The PQ_{10} value is in between $i = 2$ and $j = 3$, to accommodate good plant growth within a moderate temperature range. For the postgermination growth of rice PQ_{10} value is 2, but the relationship between growth rate and the temperature is linear, not logarithmic. However, the value of PQ_{10} decrease with the increase in temperature. For example, the respiration of rice increases with increasing temperature up to 32°C above which it declines. Between 19 and 25°C, the PQ_{10} of the respiration is close to 2, but it becomes much less when temperature range from 25 °C to 32°C.

3.3. CLAY-MIST measurement index

In this section, we derived CLAY-MIST measurement index. It is used to calculate the optimal values and these values are categorized into 4 steps which are mentioned in Table 3. According to this value, notifications are sent to

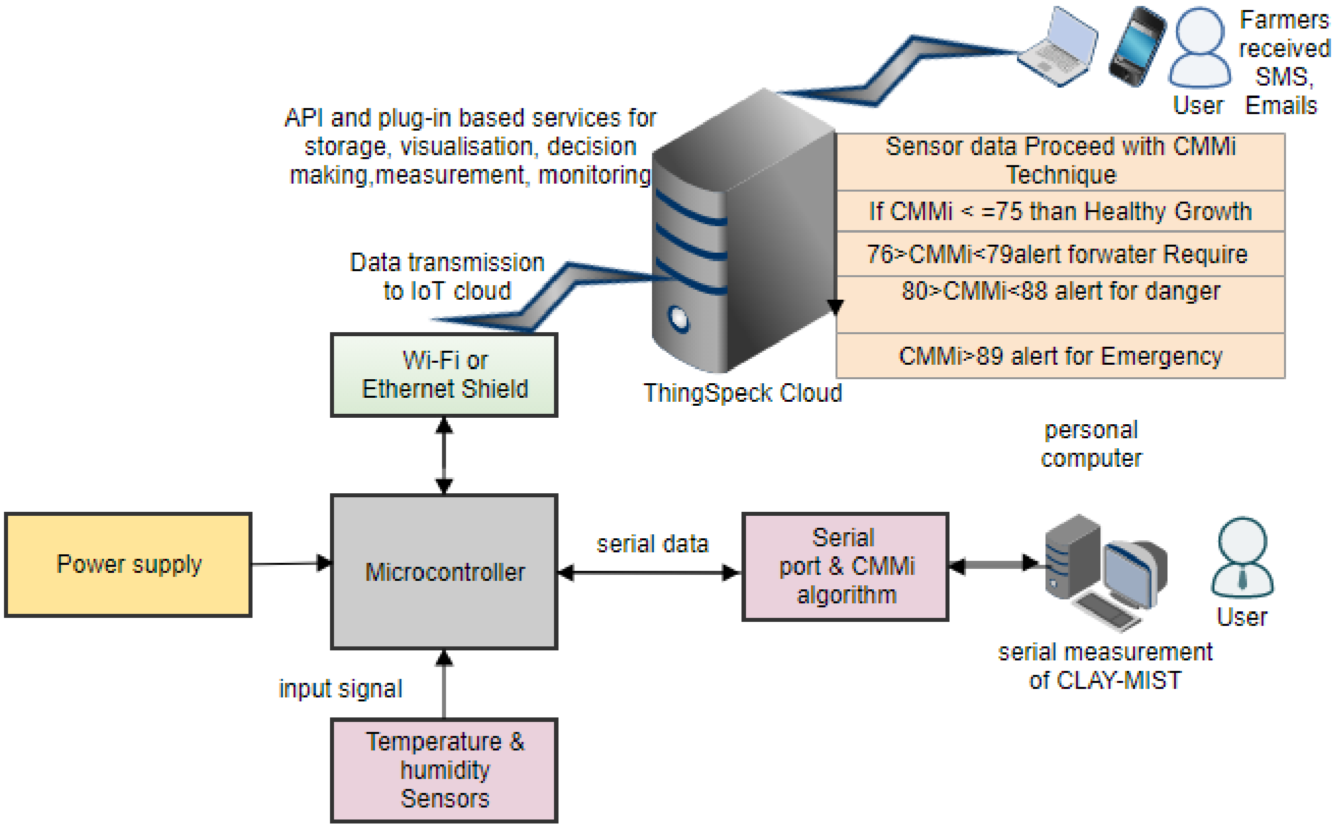

Figure 2: Agriculture CLAY-MIST measurement index IoT model.

farmers.

$$CMM_i = P \times a + b - \frac{1}{2} \times (1 - Q/100) \times (P \times a - 28) \quad (10)$$

this Equation is derived as follows

$$CMMi = f(x) - \frac{1}{2}\ RWV \times g(x)$$

$$CMM_i = P \times a + b - \frac{1}{2} \times RWV \times g(x)$$

$$CMM_i = P \times a + b - \frac{1}{2} \times RWV(P \times a + b - 58)$$

$$CMM_i = P \times a + b - \frac{1}{2} \times (1 - Q/100) \times (P \times a + b - 58)$$

$$CMM_i = P \times a + b - \frac{1}{2} \times (1 - Q/100) \times (P \times a + b - 58))$$

$$CMM_i = P \times a + b - \frac{1}{2} \times (1 - Q/100) \times (P \times a - 28))$$

The above derived CMM_i equation is used to find out comfort level of agriculture crop management. The standard constant $a = 1.6$, $b = 30$ variables are used for satisfying all abnormal conditions. As these variables are utilized to reduce processing execution time and also the results are accurate. The Eq. (9) is used to find out the cell growth with optimal value. If the result is equal to the optimal value then the cell growth is in progress, otherwise growth is stopped.

3.4. CMM_i algorithm

The following algorithm is used to calculate CMM_i index category values in a sequence of steps. In this algorithm first steps explains the connection between thingspeck and Arduino UNO board and the remaining steps are related to the calculation of Eq. (10) and Eq. (9) values. The data acquisition is processed with a DHT11 sensor (temperature and relative humidity sensor).

3.5. CLAY-MIST measurement index execution process flow

This section explains the flow of CMM_i execution process. The data collected by the sensor (temperature and relative humidity information) is used to evaluate our CLAY-MIST measurement index function. The final results are segregated in four ways based on the LWSI. This process is carried out in the sequence of steps which are shown in the figure 3.
The PQ_{10} is assessed when CMM_i value satisfies the normal level condition(CMM_i value < 76). Otherwise, remaining three conditions are executed alternately. PQ_{10} value is required to know the crop growth progress. If it satisfies first LWSI condition, then healthy growth message will be sent. Otherwise water and soil nutrients required alert message will be sent.

LWSI Category	*CMMi Values*	*Notifications*
Normal	less than or equal to 76	SMS or Mail
Alert	between 77 to 79	SMS or Mail
Danger	between 80 to 82	SMS or Mail
Emergency	83 and above	SMS or Mail

Table 3: The CMM_i categories and respective actions and notifications to farmers

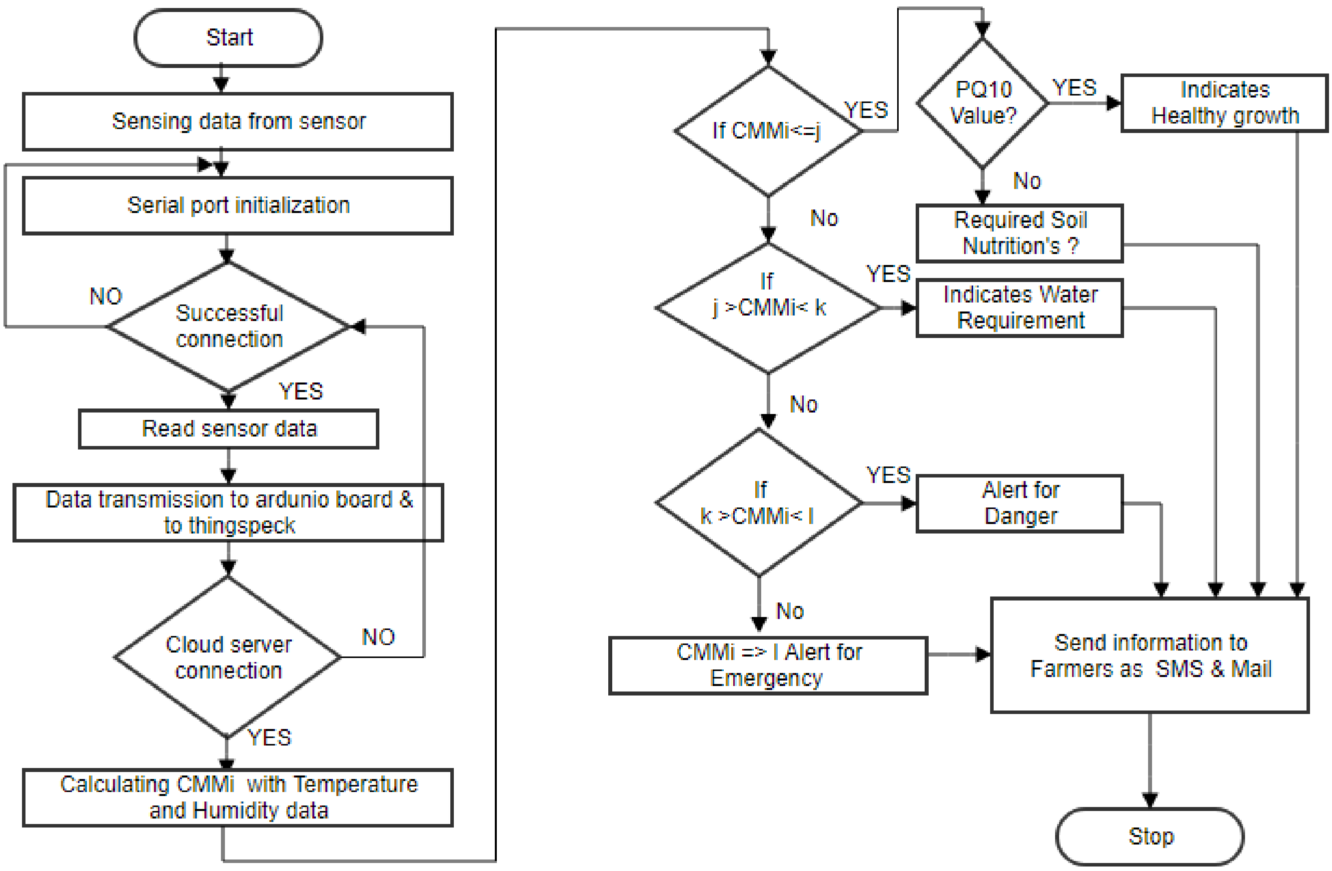

Figure 3: CMM_i execution process flow.

4. Required hardware's

The experimental setup hardware components are classified into four types:

4.1. Microcontroller

Fig 4 shows breadboard setup wire connections. Arduino Uno microcontroller has 14 advanced in/out pins, 6 analog data sources, a 16 MHz crystal oscillator, a USB association, a power jack, an ICSP header, and a reset catch.

4.2. Relative field sensors

The DHT11 sensor enables relative humidity sensor and a thermistor to measure the encompassing air (environment condition) and releases a digital signal on the information pin [operating range: temperature 50°C, relative

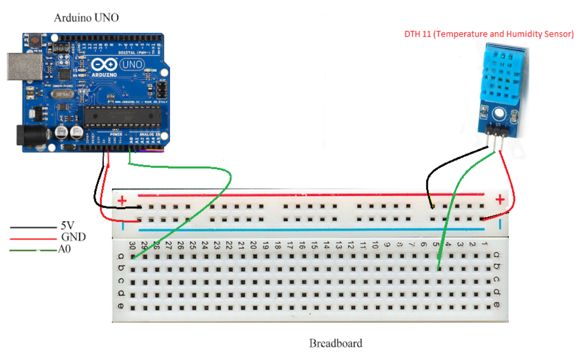

Figure 4: Arduino breadboard sensor connection.

Algorithm 1: CMM_i algorithm

Input: 1.DHT11 sensor data 2. ThingSpeak Setup
Output: CLAY-MIST measurement index values and notifications;
initialization;
int P, Q, b=30, i=19, j=75, k=79, l=89;
float a=1.6, c=2.01, d=3.01;
double CMM_i, PQ_{10};
while $P \mathrel{!}= 0 \;||\; Q \mathrel{!}= 0$ **do**
  Read P, Q ;
  $CMM_i = P \times a + b - \frac{1}{2} \times (1 - fracQ100) \times (P \times a - 28)$;
  if $CMM_i < i$ **then**
    Print: low temperature ;
  else
    if $i > CMM_i < j$ **then**
      $\text{PQ}_{10} = \frac{Rate\ at\ (P+10)}{Rate\ at\ (P \times 2.5)}$;
      if $c > PQ_{10} < d$ **then**
        Print: Healthy growth;
        Print: max comfort level;
      else
        Print: No Healthy growth;
        Print: Nutrition's and optimal water level needed;
        Print: Alert notification sent;
      end
    else
      if $j > CMM_i < k$ **then**
        Print: Danger notification sent;
      else
        if $CMM_i > l$ **then**
          Print: Emergency notification sent;
        end
      end
    end
  end
  Print: invalid output;
end

moistness 20% to 90%]. The DHT11 sensor is considered because of its similarity with Arduino Uno, low power abilities, exactness and precision rates are reasonable in our research point of view.

4.3. Communication protocols

IEEE Std 802.3ae-2002 convention based Arduino Ethernet shield has enabled in the investigation. MQTT stands for message queuing telemetry transport. CloudMQTT gives machine-to-machine communication to manage with message servers in the cloud.

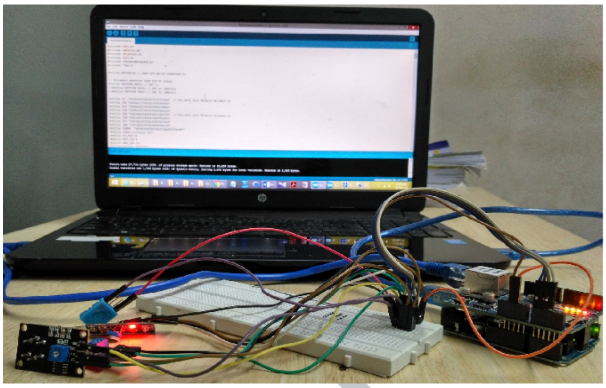

Figure 5: CLAY-MIST measurement index experimental setup

4.4. IoT cloud server services

The below-mentioned ThingSpeak cloud platform has chosen for this experiment based on Application Programming Interface (API) for interconnectivity of the proposed framework. The programming interface is an arrangement of schedules, tools, and protocols for building programming applications. It causes the engineer to connect the cloud to perform information perception, stockpiling, examination, and activating purpose.

At first, the microcontroller board is appended with the DHT11 sensor and Ethernet shield connected via a serial port of a laptop computer in which Arduino UNO is preinstalled. Similarly, ThingSpeak is ready with specific APIs to communicate with the system. An appropriate algorithm is coded on the IDE and installed into the board. A user sitting at the local laptop machine or remote location can access the real-time information from the board and sends to the cloud respectively. Fig. 5 shows the experimental design comprising a laptop, Arduino Uno, Arduino Ethernet shield, a DHT11 placed over a breadboard connected with wires represents the IDE along with program running on Arduino UNO and the serial monitor output.

5. Result analysis

The results are categorized in three ways 1. ThingSpeak out 2. Plotly output 3. Serial output. These are explained with graphical representations are given below.

5.1. ThingSpeak output

Fig.6 shows the ThingSpeak output resembling the user sitting on the terminal to view the IoT cloud output. It clearly shows the graphical representation of temperature, relative humidity, CLAY-MIST measurement index values along with the representation of meter gauge. The yellow color shows the danger alert notifications, and red color shows the emergency. If CLAY-MIST measurement index value comes under the LWSI categories of alert, danger and emergency, then notifications or messages are sent to farmers. The related plug-in to monitor gauge meter is given below https://thingspeak.com/apps/plugins/178859.

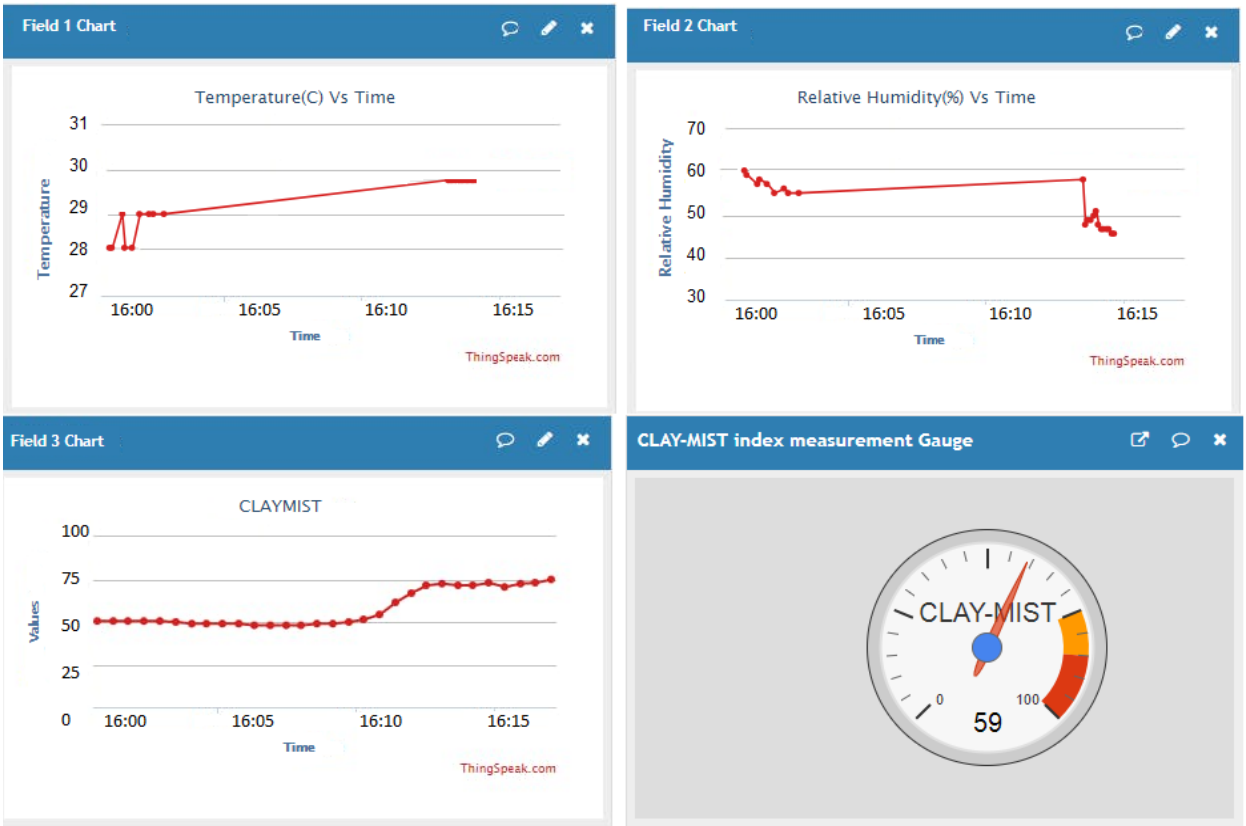

Figure 6: CMM_i ThingSpeak IoT output

5.2. Plotly output

Figs. 7 and 8 shows the graphical representation based on real-time data which is obtained from the experimental setup. If the first LWSI category is normal, then this category is again classified into two types. They are maximum and minimum comfort levels. If the temperature and relative humidity values are at the normal level, then it is considered as minimum level otherwise maximum comfort level. Temperature Quotient (PQ_{10}) proposed to calculate cell growth at a particular point of temperature. It plays a vital role to take necessary action for healthy growth. The x-axis shows time interval and Y-axis shows the values of related measurements. https://plot.ly/mekalashareef/plot1. These graphs display the values in horizontal and vertical axis to make comparison.

Fig.8 shows all LWSI categories which are given in Table 3 and these are compared with CLAY-MIST measurement index values.

5.3. Serial output

It resembles the user using the laptop to view serial monitor output through serial port pin COM4 in Fig. 9. The diagram shows the communication and connection between the system and the proposed model which represents the notifications based on the CLAY-MIST measurement index value. This process is iterated periodically and again start sensing data streams to cloud for further process. The results show the values of CLAY-MIST measurement index and temperatures are 59% and 29°C respectively. It seems that maximum comfort of normal level of LWSI category. So it represents max comfort level and also the temperature value reached the optimal value of temperature quotient (PQ_{10}). Hence, it selects healthy growth decision shown in Fig. 9. These results are evaluated and processed in IoT cloud server to monitor agriculture field remotely which is the comfortable process for farmers. Fig. 10 shows comparison between existing systems and proposed measurement system. The clay mist measurement index function is used to overcome the problems of the existing techniques. This graph differentiate multiple models in terms of performance and accuracy of results. On x-axis represents time interval(minutes) and the y-axis represents measurement values of all methods

Fig. 11 manifests a comparison of CLAY-MIST measurement index accuracy with existing systems. Most of the existing systems fail to measure the accurate value during winter and rainy season ($[-5, +5] \leq measurement \leq [-19, +19]$). For instance, If the temperature is 29°C and relative humidity is 56%, then CLAY-MIST measurement index evaluate accurate results than existing approaches which are updated in Table 4. We can perceive that our system has accurate measurement value with less error rate than remaining systems and it plays a significant role at

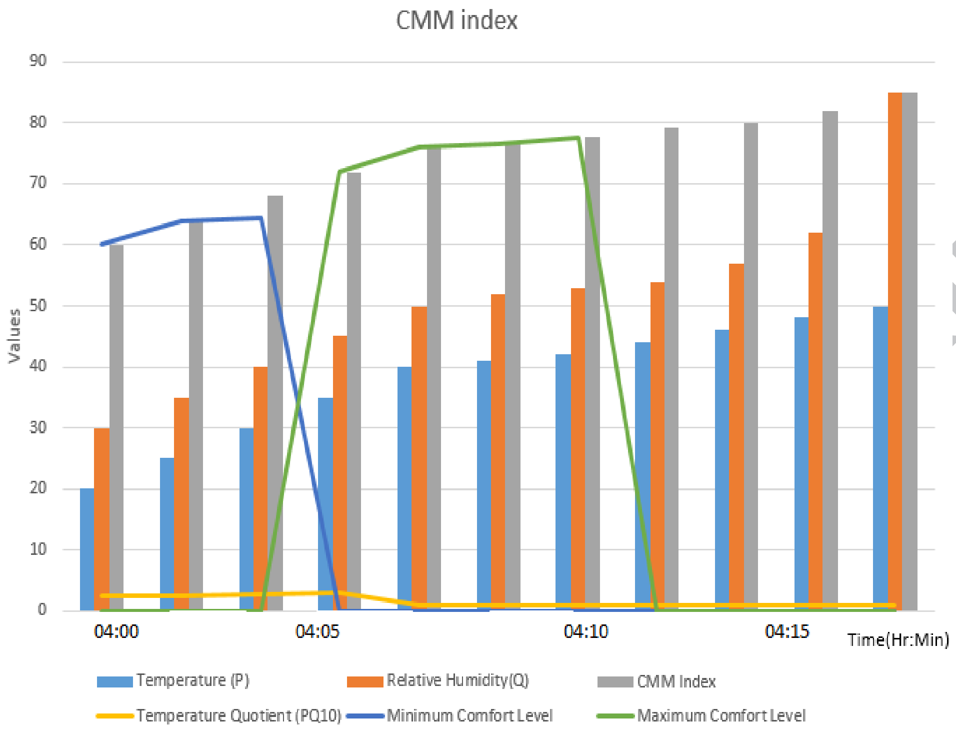

Figure 7: CMM_i Plotly based IoT output

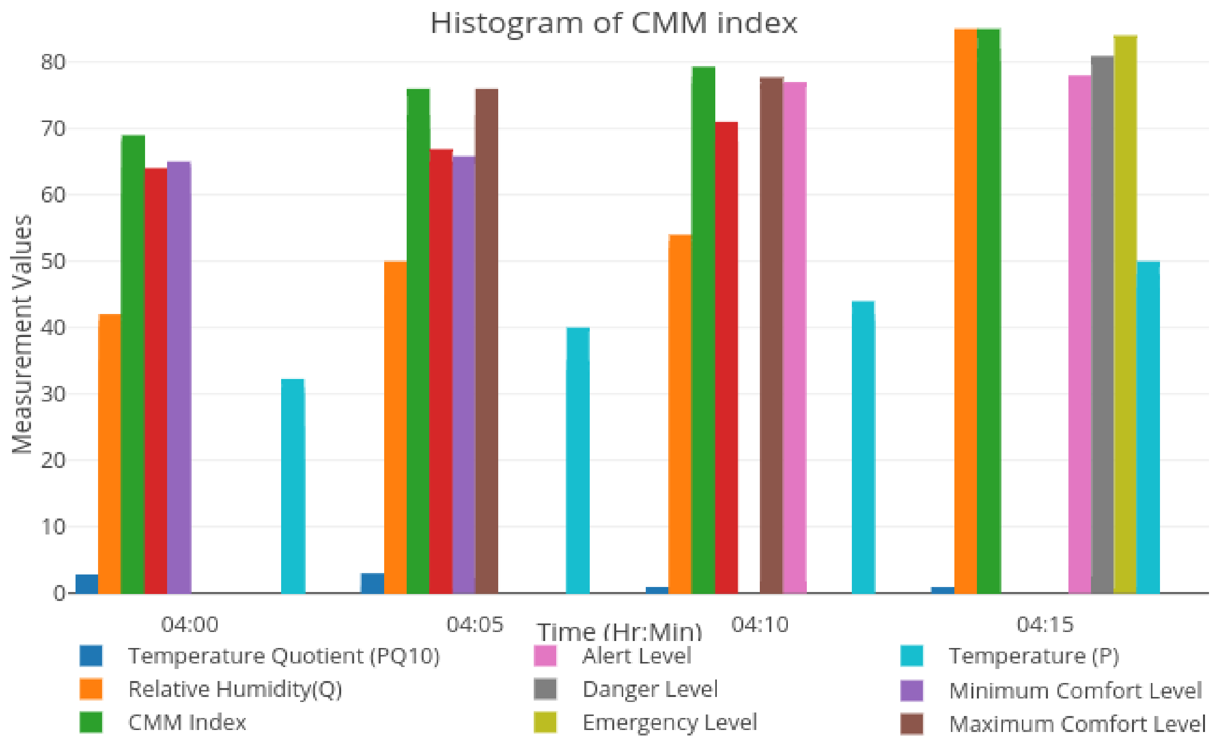

Figure 8: CMM_i histogram output

the peek abnormal conditions. The CLAY-MIST measure-
345 ment index exactly evaluates the amount of air humid dur-
ing rainy and winter seasons.

Table 4: Experimental input parameters such as temperature is 29°C, relative humidity is 56% and relevant dewpoint to measure all approaches value

S.No	Type of index	Cool	Normal	Alert	Danger	Emergency	Measured value	Error rate(%)
1	TH	-	<27	27 - 32	32 - 54	$\geq$ 54	30.312	0.4026
2	Humidex	-	<30	30 - 40	40 - 55	>55	31.515	0.3525
3	AT	6 - 17	<18	18 - 24	24 - 30	>30	32.869	0.3259
4	ET	9 - 17	17 - 21	21 - 23	23 - 27	>27	25.656	0.3117
5	CLAY-MIST	14-39	40 - 76	77 - 79	80 - 82	>83	59.035	0.2539

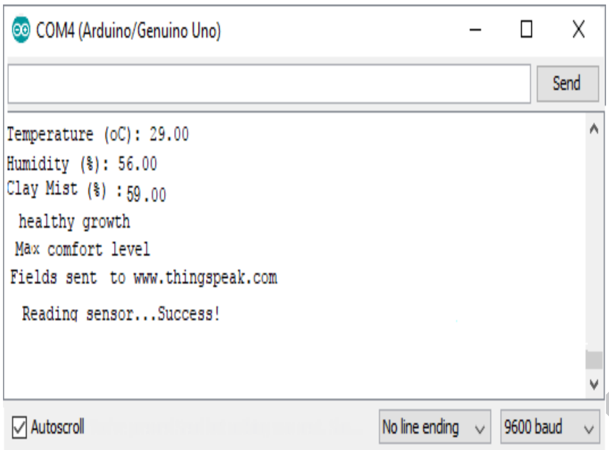

Figure 9: CMM$_i$ serial port output

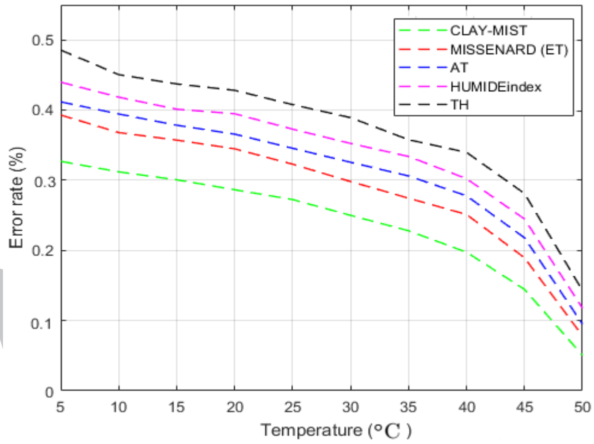

Figure 11: The CMM$_i$ has less error rate than other existing measurements when temperature is 29°C and relative humidity is 56%.

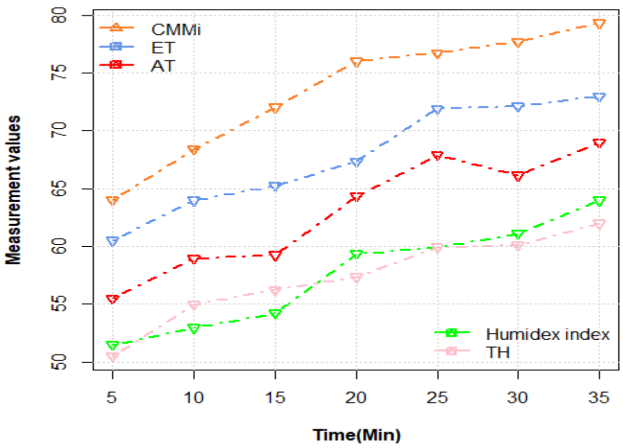

Figure 10: CMMi comparison with existing measurements

6. Conclusion

We proposed a novel CLAY-MIST measurement index function to find the comfort levels of agriculture crop. The real-time data has been used to assess the level of thermal comfort in terms of CLAY-MIST measurement index. The temperature quotient (PQ_{10}) function is innovated and it is used to extract the cell growth. If it reached the optimal value, then it will act as a parameter for taking a successful decision executed on ThingSpeak, results are formulated successfully. This smart measurement system advocates the monitoring of thermal comfort in terms of livestock weather safety index categories and the assessed results shows direct advantages to healthy growth agriculture crop leads to 75% comfort level. IoT-cloud based CLAY-MIST measurement index implementation is an innovative methodology which is used for the measurement and monitoring purpose. It reduce 6% of error rate and 37% of sensor data processing time compared with existing techniques. The proposed framework can send notifications to the client according to the livestock weather safety index categories. Therefore, the farmer can take appropriate action for healthy growth of agriculture crop field.

Acknowledgment

The authors would like to thank the computing center of VIT University for the sincere cooperation in providing facilities.

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