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Remote Monitoring and Automated Control of Silkworm Rearing to Improve Yield

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Abstract

Sericulture denotes to the rearing of silkworm to provide silk. Environmental parameters are the important factors in the growth of silkworms. Maintenance of these parameters at an optimal level is difficult for Seri culturists as most of them are untrained and the procedure is quite laborious and time consuming. Parameters like Temperature, Humidity, Light intensity, Air Quality and air pressure are the important factors for proper growth of silkworms. The aim of this proposed work is to build an automated monitoring system which maintains the parameters at optimal values to aid effective growth of the silkworms. The proposed model is built using multiple Node MCU as client nodes and Raspberry Pi as server. MQTT (Message Queuing Telemetry Transport) protocol is used for transmitting data between clients and server. MQTT is a light-weight messaging protocol which works on Publish – Subscribe communication model which consists of Publisher, Subscriber and Broker. Node MCU which is used as an end device acts as a publisher by capturing data from Temperature, Humidity, Light, Carbon monoxide and air pressure sensors and transmitting it to the server. The server processes the sensor data received from multiple Node MCU and compares it with the threshold values assigned to each parameter being monitored. If any deviations are found in the parameters beyond the threshold value respective actuators for each sensor are activated through relays. Using this system, the rearing room parameters can be maintained at optimal values which is suitable for effective growth of silkworm to provide better yield.

Keywords— Silk worms; Sensors; Client; Server; MQTT; Automation.

I. Introduction

In India, silk employs around 8.7 million people in rural and semi-urban areas. India is the world's second-largest silk producer. Among the four varieties of silk produced in 2020-21, Mulberry accounted for 70.72% (23,860 Metric Tons), Tasar 8.02% (2,705 MT), Eri 20.55% (6,935 MT) and Muga 0.71% (239 MT) of the total raw silk production of 33,739 MT [15]. Mulberry silk accounts for nearly all of the world's silk production. The silkworms of the Bombyx mori/ Biovoltine moth feed on the leaves of the mulberry plant, Morus indica, to produce this silk. Mulberry bushes have wide-spreading branches and are perennial. To supply sustenance for the silkworms, they are particularly cultivated, manured, and cared after. Sericulture is an important occupation in India and the techniques used by the seri culturists are still manual. Parameters like temperature, humidity, light intensity, flow of fresh air and quality of air are the important factors in the growth of silkworms. These parameters are critical to get better quality and quantity of cocoons. These parameters have variations at different stages of growth in the 26 days of its life cycle. It is very difficult to maintain these parameters manually to the accuracy required. Maintenance of these parameters is difficult for seri culturists as most of them are untrained. Labourers working in the rearing centers have to monitor the parameters on a regular basis and be aware of the different parameters to be maintained for proper growth of silk worms. Even if one parameter is mishandled worms die due to viral diseases like Grasserie, Flacherie etc. infection in worms affects their physiological activities and the quality and quantity of as well as reduce the profit. Health of the labourers are affected as the rearing centers have lot of chemicals sprayed to maintain good hygiene so that worms do not get infected. Labourers exposed to various chemical and biological elements leads to different health problems like allergies, respiratory diseases, irritation in the eye and musculoskeletal disorders. Setting up an automated system avoids labourers entering the rearing center often which in turn reduces the worms getting infected. It is predicted that sericulture done in tropical environmental regions and various regions in India is expected to be severely impacted [11] by a rise of 2 degree Celsius or more in average annual temperature, though small to marginal losses are expected in Jammu Kashmir and Sub-Himachal Pradesh. According to agricultural studies, the total revenue loss in sericulture might range from 10% to 20% in temperate regions hence it is very important to maintain required environmental parameters through automation. There are various breeds of silkworms in India. The proposed model has been experimented with bivoltine breed of silkworm. This breed of silkworms requires around 26 degree Celsius of temperature, 65-75% of humidity, 600-700 lumens of light to be maintained in the rearing room for effective growth of silkworms.

The rest of the paper is organized as follows: section 2 covers research on various models which were previously developed in automating sericulture, section 3 explains methodology of the proposed model and section 4 demonstrate the results obtained by implementing the developed model in the rearing room.

II. Related Work

In the field of sericulture, different studies have been done. The research covers creating a room parameter tracking and disinfection system using 6LowPAN(IPv6 over Low Power Wireless Personal Area Network) powered Internet of Things (IoT) based technique. Image processing is used to identify phases of the silkworm life cycle. This model uses CoAP (Constrained Application Protocol) and RPL (Routing Protocol for Low Power and Lossy Networks).Air condition actuation has been included in the system. It is achieved using Contiki OS (Operating System). Sensors such as humidity and temperature is used with TelosB motes to build this system. The actuation is done in a very small scale by incorporating only air condition system in the rearing room [1]. The model is developed using ARM7 microcontroller to monitor rearing room parameters along with the disinfection system. Web camera is interfaced with microcontroller to observe and track silkworm. Image processing is used to identify any illness in silkworms and medications or pesticides are sprayed by the disinfection system which is connected to microcontroller, along with this temperature sensor is connected to the microcontroller to sense the room temperature. Microcontroller can only perform limited number of executions and the processing speed is low [2]. The models are developed using IoT where Node MCU is used to connect sensors like temperature and humidity and actuators like fan, LED and water sprayer is connected to it to control the parameters. Since all the sensors and actuators are connected to a single NodeMCU it causes heavy load onto the microcontroller [3][8].

Models have been interfaced with Wireless Personal Area Network (WPAN) along with Arduino board to measure room parameters like humidity and temperature in the rearing room. A single unit cannot measure the room parameters of entire rearing room effectively [4]. A zone based system is developed

to monitor rearing room parameters. The system consists of data processing sub-system along with master control facility. The zones are connected to master control facility which manages all the activity. The sensor values are collected and fed to the computer. MATLAB software which is present in the computer process the data. Based on the corrective actions the actuators connected to computer are activated. Since the data has to pass through the computer the system is not flexible and time taken to process the data would be large [5].
Another model uses STM32 microcontroller to collect data from humidity and temperature sensor. Data from sensor is logged into an oracle database. Stored sensor data is used to perform Machine Learning and study environmental changes in the rearing room. Only one sensor is used to capture the rearing room parameters and actuation is not implemented in the system [6].
GSM module is interfaced with Arduino to monitor and control rearing room parameters like humidity and temperature. Sensors are connected to Arduino which is in turn connected to GSM module which sends the rearing room parameters as SMS to farmer's phone. The messages cannot reach phone from GSM module when there is poor connectivity of network [7] [10]. The model uses NodeMCU to which sensors like humidity, light and temperature is connected. The NodeMCU is connected to blink application through the inbuilt Wi-Fi module in NodeMCU. The microcontroller will sense the room parameters and sends it to user phone using Blink server. Model has been built only to display the rearing room parameters [9].

A model is developed where temperature sensor, humidity sensor and light intensity sensor is connected to NodeMCU . The variation in sensor parameter will be sent to user phone as a notification through Wi-Fi, this model monitors the rearing room parameters but does not automate [16]. Similar model is developed which monitors light temperature and humidity parameters in rearing room using sensors, these sensors are interfaced to ATmega328/P microcontroller, the sensors are connected through Wireless Sensor Network using star topology [17]. A supervisory model is developed using Arduino and GSM Technology, along with temperature, humidity and light, carbon dioxide content and fire accidents are also monitored [18]. Apart from monitoring various automation model have been developed to handle the silkworms in rearing room [19] [20].

Methodology

The present work has been carried out for bivoltine breed of silkworms. The model has been developed using MQTT protocol due to its unique features such as less payload and low power consumption and also to establish communication between server and multiple clients.
Multiple Node MCU unit to which various sensors are connected is placed at different corners of rearing room. The NodeMCU acts as end devices which will capture sensor data from temperature, humidity, light, air pressure and carbon monoxide (CO) sensors and transmit to MQTT server established using Raspberry Pi. The server will collect data from multiple NodeMCU and processes it. The obtained sensor data is compared with the threshold value which is set for optimum growth of silkworms. The data on MQTT Server can be viewed remotely from anywhere using mobile by subscribing to MQTT topics. MQTT topics are a type of addressing that enables MQTT clients to communicate with one another. Using the forward slash (/) as a delimiter, MQTT Topics are organized in a hierarchy analogous to folders and files in a file system The monitored sensor values are also tabulated in the text file for aiding analysis. Analyzing

the data aids in identifying the relationship between yield before and after installation of actuators and to optimize the values in the future based on the breed of the silkworms.A room is chosen in University of Sericulture, GKVK Campus, Bangalore to implement the project in real time.

Block Diagram

For multiple devices to transfer data to a single server, client-server setup is established. The communication between server and clients takes place through MQTT protocol. The units which capture and send the sensor data are identified as publishers. The server which collects the sensor values from multiple publishers are identified as broker. The units which subscribe to sensor data like mobile phone is identified as subscriber. Four different NodeMCU units all containing similar set of sensors are placed at four different corners of the rearing room. The block diagram shown in Fig. 1. consists of sensing unit, IoT enabled module and the server, the sensing unit consists of various sensors such as Light sensor, humidity sensor, Temperature Sensor, CO sensor and air pressure sensor, the sensors connected to the IoT enabled sericulture module senses various parameters and passes on the value to the server. The server collects the sensor values from different IoT modules, process the values and compares the obtained sensor values with the threshold value. If the sensor values is not within the threshold range then the respective actuators are activated using the relays. The sensor values are checked continuously. The sensor values can be monitored from remote location using MQTT app in android. The obtained sensor values are also stored in text file for analysis purpose.

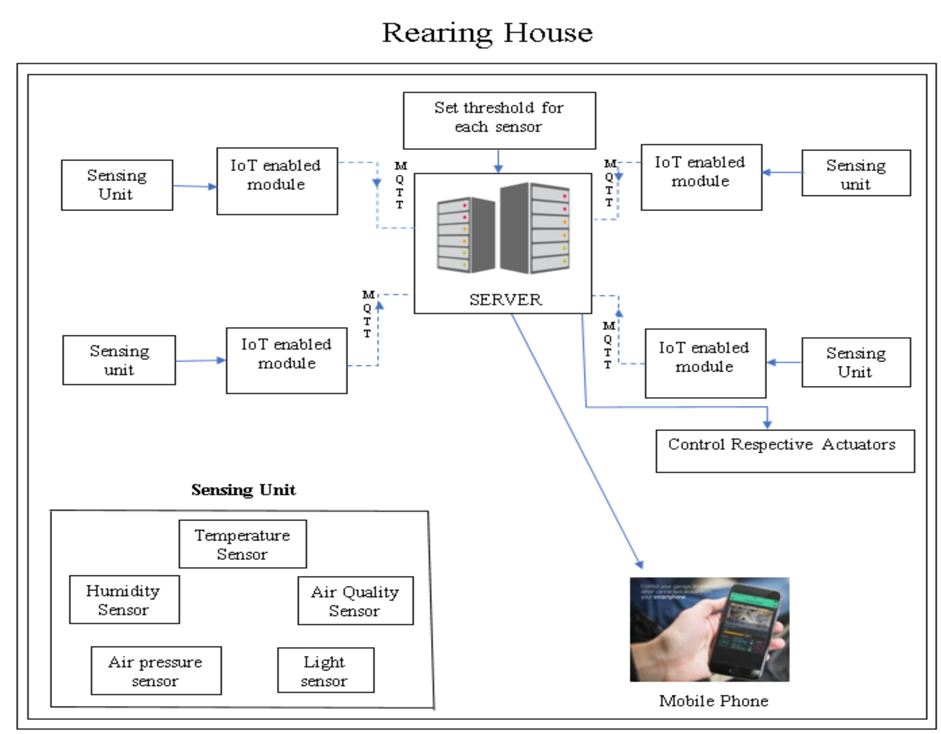

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Figure. 1. Block diagram of sericulture automation system.

Flow Chart

Figure 2 shows the flowchart of the proposed system. Initialization of Wi-Fi system takes place along with server and client modules. During the initialization, connection is established between server and clients. Establishment of connection takes place by the credentials defined in the code. Once the connection is formed initialization of all the sensors like temperature sensor, humidity sensor, light sensor, air pressure sensor and carbon monoxide sensor takes place. For each sensor the threshold values are set suitable for the effective growth of silkworm. The multiple NodeMCU units which are placed at different corners of the room i.e., publishers of sensor data connected to various sensors starts sensing the data and pass on the sensor values to the server. The server which is Raspberry Pi collects data from publisher and processes the data received from multiple publishers. The processed data is compared with the preset threshold. The ideal temperature for bivoltine breed of silkworm is around 26 degree Celsius. Ideal humidity suitable is 65-75% and ideal amount of light to be maintained is 600 to 700 lumens. The ideal air pressure to be maintained in the room 8 Pascal. The ideal carbon monoxide value to be maintained is 5-15 ppm. If the data is out of the threshold then respective actuators are activated. The Heater is turned ON/OFF if values from temperature sensor is out of the threshold, similarly cooler/humidifier is turned ON/OFF if humidity sensor value is out of threshold, lights are turned ON/OFF if values from light intensity sensor goes out of threshold, blower is turned ON/OFF if values from air pressure sensor goes out of threshold and exhaust fan is turned ON/OFF if values from carbon monoxide sensor goes out of threshold. Likewise all the actuators are activated and the environmental parameters are brought back to threshold suitable for silkworm. The data which are continuously sensed are stored in a text file. This text file is automatically sent over mail to the specified mail ID in the code at regular intervals of time.

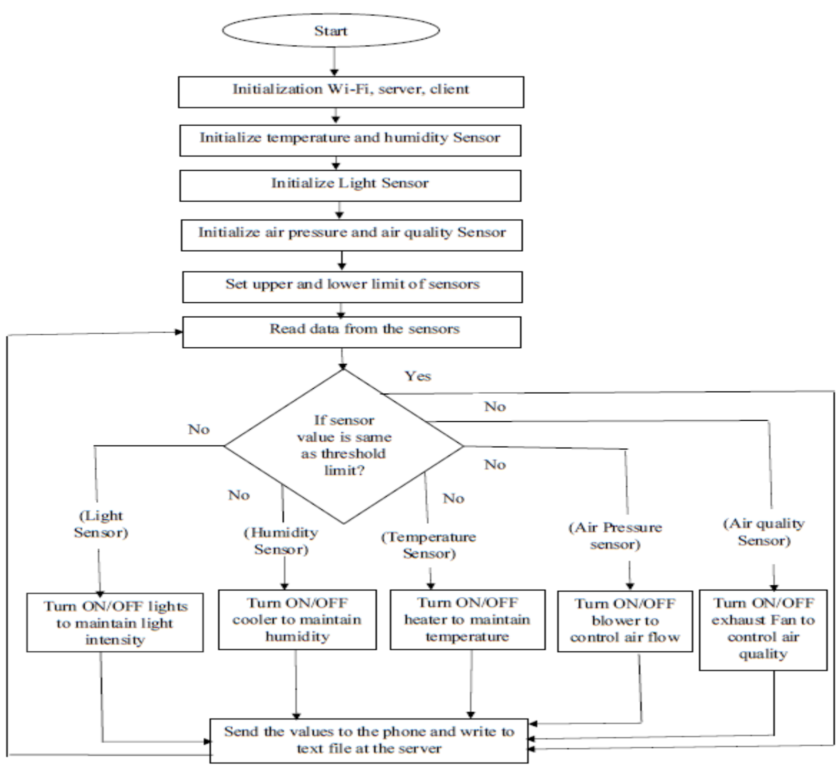


Figure. 2. Flow chart of sericulture automation system.

The sensor data that is collected by the server can also be viewed in mobile phone using an MQTT application by subscribing to topics of the sensor publishing the data. The real time data can be viewed in mobile phone in any remote location.

Flow chart of communication between publisher and server is as shown in Figure 3. The sensor data collected by multiple NodeMCU is passed on to the server using MQTT protocol. The NodeMCU is coded using Arduino IDE. First the libraries are included such as ESP8266wifi, PubSubclient, DHT, etc., and required variables are defined in the code. The credentials required for Wi-Fi connection such as username and password is initialized. Using the credentials NodeMCU establishes connection with Wi-Fi. The status of connection is displayed on the console. Once the NodeMCU is connected to Wi-Fi, establishment of connection to server takes place. After the establishment of connection with server the NodeMCU will start reading the sensor data and stores it in variables. TCP/IP port1883 is used for transmission of data in MQTT. Sensor from each NodeMCU is assigned specific topic to identify the node from which the sensor values are passed. rearingroom/sensordevice/lightsensor/corner1 is an example of a topic. The sensor data stored in variable is converted to suitable form to send it to server over MQTT protocol. When a new data is published under a topic it is automatically delivered to all the subscribers of the topic in MQTT. This process repeats continuously. If connection between publisher and server breaks then the NodeMCU attempts to connect to server automatically else the NodeMCU constantly sense the values and publish it to the server.

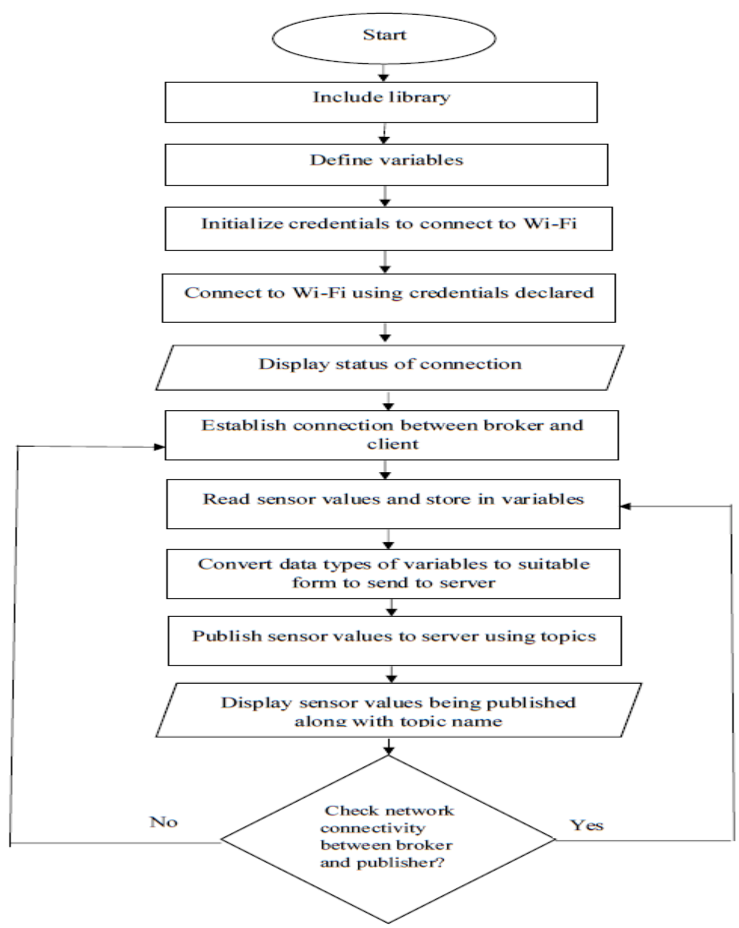


Figure. 3. Flow chart displaying communication between publisher and server.

Flow chart of activity between server and subscriber is as shown in Figure 4. The server Raspberry Pi is coded using python language. Various libraries are imported such as Pahomqtt, SMTP, Date, Time etc. Python MQTT has an inbuilt function called connect (). Using this connect function connection is initialized to the clients and the status of connection is displayed. Once the connection is established, client objects are created for each clients. Through this client objects each NodeMCU is connected to the server. The mail function which automatically mails the text file in which the sensor data is stored is initialized.

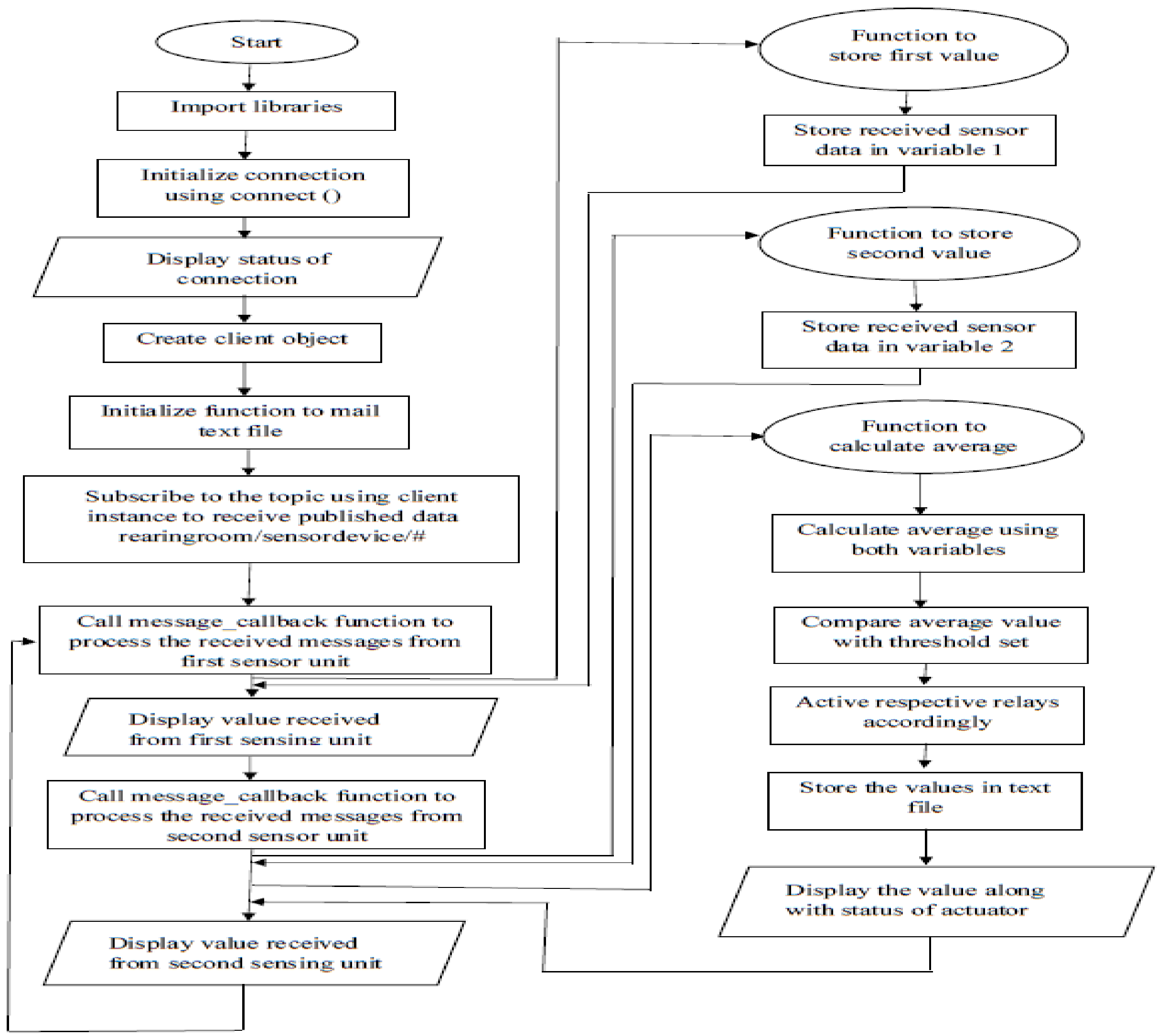


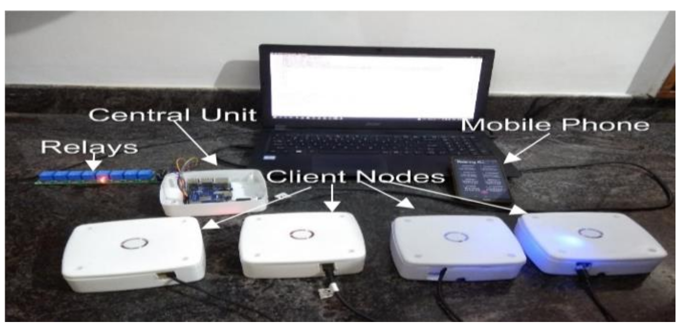
Figure. 4. Flow chart displaying activity between server and subscriber.

Then the data which is published by the IoT modules are received by subscribers based on the topics for which they have subscribed. The topic has to be subscribed using client instance so that the messages published for each publisher can be received simultaneously, example of how the topics are subscribed is rearingroom/sensordevice/#. The received sensor data has to be processed. To process the received sensor data message_callback function is used. This function will collect the incoming data and stores it in defined variable. Each sensor value which is received from the sensor is displayed on the console for convenience. Separate function is written to store the values from each publisher. Each sensor value which is being sent to their respective functions are displayed in the python shell. Then the sensor values that are stored into variables are passed on to a different function which calculates the average using the variables in which the values are stored and the average value is displayed. The average value is compared with the threshold value set in the server. If the average value is not within the threshold limit then their respective actuators are activated through relays. Actuators such as heater, humidifier, lights, blower and exhaust fan are activated for temperature, humidity, light, air pressure and carbon monoxide sensor respectively. This process runs continuously and the parameters within the rearing room are maintained. The sensor data which is collected by the server is written to the text file. Data in text file helps in analyzing the collected data. This text file is automatically sent to specified mail ID in the program for specified duration of time. Hence the parameters in the rearing room can be accessed and monitored remotely. The sensor data that is collected by the server can also be viewed in mobile phone using an MQTT application by subscribing to topics of the sensor publishing the data. The real time data can be viewed in mobile phone in any remote location.

Results and Discussion

The setup of the model as shown in Figure 5 ,consists of different sensing unit modules, along with the server Raspberry Pi and the relay connected to the server. All the modules are connected to the wall socket for power supply. The data between the modules are transferred wirelessly using MQTT protocol. The server receives the data from multiple publishers. The server will process the data. Compare the results with the threshold value set and respective relays are activated.

Figure. 5. Setup of the developed.



The figure 6 shows the connection of relays with the server along with actuators. The relay will be activated when the respective sensor value goes out of the threshold value set.

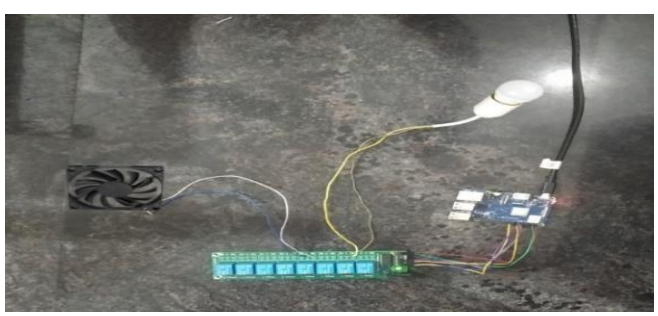


Figure. 6. Server Raspberry Pi connected to relays and actuators.

The Figure 7 and Figure 8 shows the module installed in the rearing room. The sensor modules are placed at four multiple corners of the rearing room so that the entire room parameters could be monitored and it could be brought to the required optimal values in the rearing room. Sensor module which is installed in one end of the rearing room is plugged to the wall socket for power supply. The sensor node was installed to collect room parameters from the rearing room.
Figure 8 shows the sensor module which is installed at the other corner of the rearing room along with the central unit Raspberry Pi which collects the sensor data from multiple parts of the room. The data is transferred wirelessly, hence the router is placed to support the wireless transmission as shown in the figure.

Figure. 7. Publisher module installed in the rearing room at one end of the room to collect data.

The temperature sensor data, humidity sensor data and light sensor data which was collected for a span of ten days is plotted against day and time. The figures are plotted by considering five intervals in a day.

Figure. 8. Publisher module installed in different corner of room along with server module to collect rearing room parameters.

Over a period of ten days there is variation of temperature from 23 degree Celsius to 29 degree Celsius as shown in figure 9 which is not suitable for silkworm. Silkworm requires an average of 26 degree Celsius to be maintained in the rearing room which is crucial for their effective growth. Heater is used in rearing room to maintain the temperature within threshold which gives silkworm a suitable temperature for effective growth.

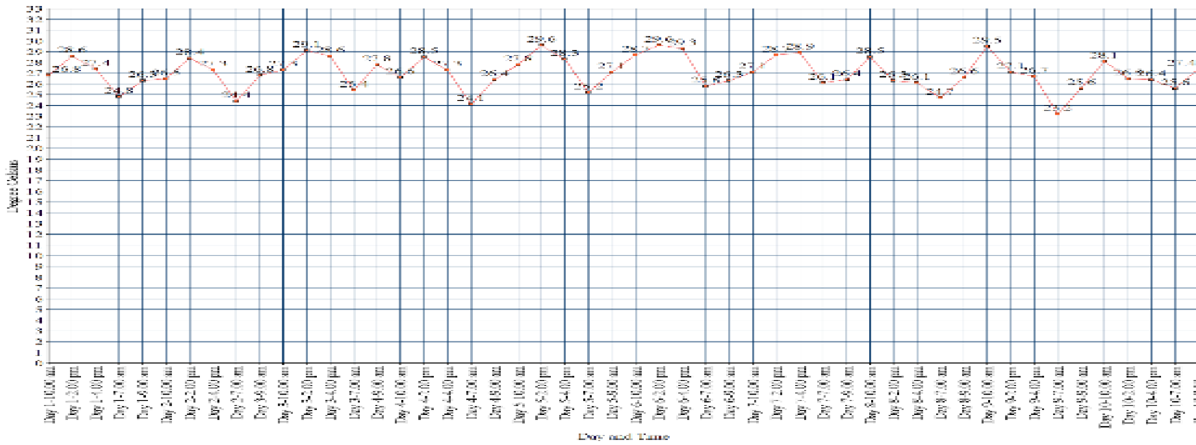


Figure. 9. Variation of temperature sensor value over a period of 10 days extracted in rearing room.

The humidity value varies from 40% to 50% in the rearing room over a period of ten days as shown in figure 10. The suitable amount of humidity to be maintained for silkworm should be 65%-75%. The actuator is turned ON/OFF if the humidity value is not within the optimal range. Humidifier is used in rearing room to maintain the humidity within threshold which gives silkworm a suitable environment to grow.

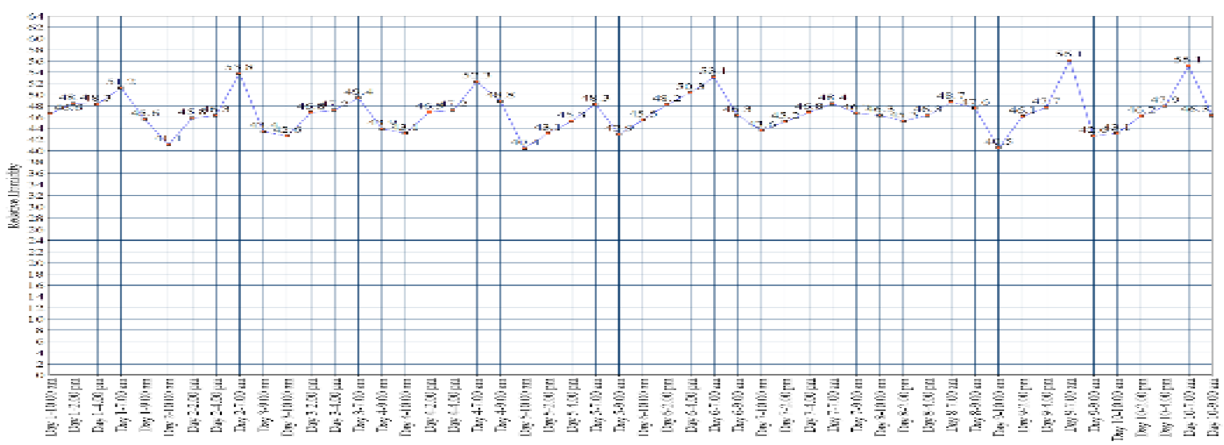


Figure. 10. Variation of humidity sensor value over a period 10 days extracted in rearing room.

The light value varies from 300 to 1000 lumens over a period of ten days as shown in figure 11 which is not suitable for the effective growth of silkworm. The required amount of light for the silkworms is 600 to 700 lumens. Which has to be maintained for the effective growth of silkworms. Light bulbs are used in rearing room to maintain the light intensity value within threshold which gives silkworm a suitable environment to grow.

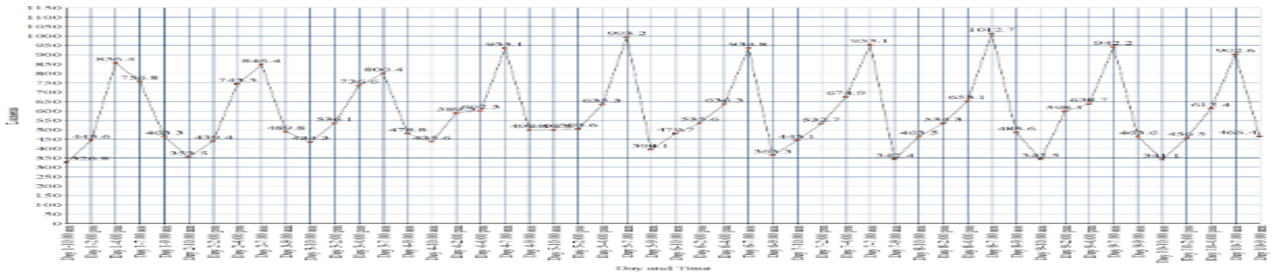


Figure. 11. Variation of light sensor value over a period 10 days extracted in rearing room.

The set up will sense the environmental parameters and continuously compare with the threshold set. If the room parameters go out of threshold the respective actuators will be activated and the room parameters will be brought back to threshold. The model senses five parameters such as temperature, humidity, light, carbon monoxide content in the air and air pressure value in the rearing room. If the parameters vary apart from these threshold the silkworms might be in danger because of the variations in environmental parameters, which is not suitable for their effective growth. So it is very important to maintain these parameters. These units were implemented in real time for temperature, humidity and light intensity sensors with actuators heater, humidifier and lights respectively in the rearing room. The remaining sensor which were connected i.e. air pressure sensor and carbon monoxide sensor were tested as prototypes.

The sensor values which are captured by the server is stored in the text file. The stored text file is automatically mailed by the server to the specified mail address for every interval mentioned in the code for remote analysis. The screenshot of the data stored in text file being sent to the mail for specified interval is shown in figure 12.

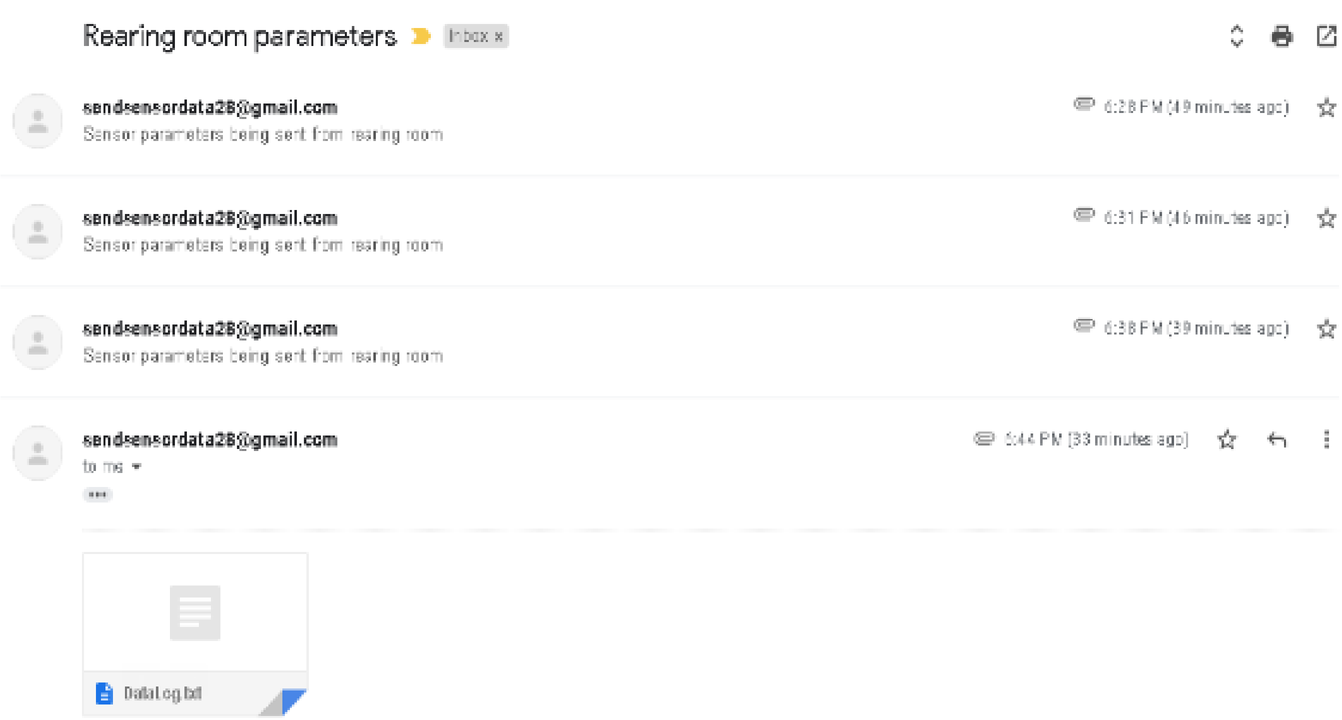


Figure. 12. Sensor data read is stored into text file automatically sent to mail for every specified interval.

The sensor values received by the server are also sent to the mobile phone using MQTT dashboard app in android play store. The user can access the data from any remote location and check the values in the rearing room any time by subscribing to the topics of publishers. The screenshot of the value displayed on the mobile is shown in Figure 13.

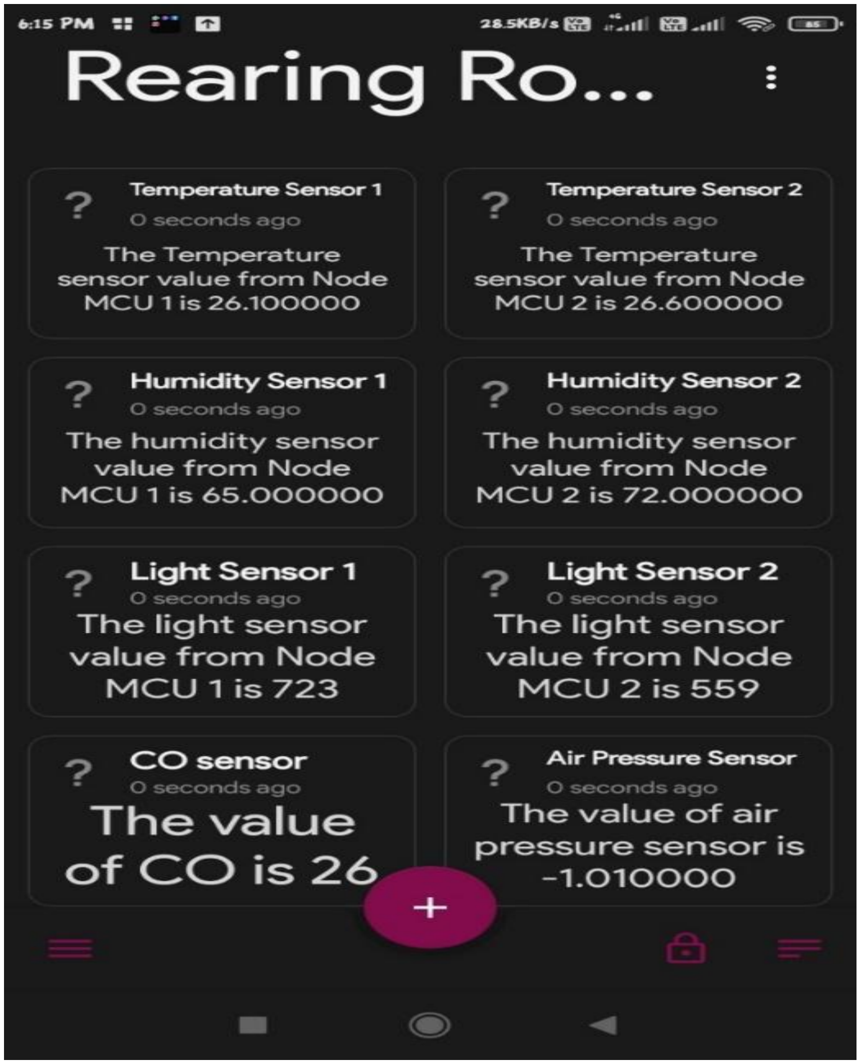


Figure. 13. Sensor data captured by phone in remote location using MQTT app.

Conclusion and Future Scope

Multiple client server model to automate the control of rearing room parameters is developed using IoT, where various sensors connected to NodeMCU like light, humidity, temperature, carbon monoxide and Air pressure sensor monitors the parameters in the rearing room. If the parameters drift from the threshold the silkworms might be in danger because the environment apart from this is not suitable for their growth. So it is very important to maintain these parameters. The set up will sense the environmental parameters and continuously compare with the threshold set. If the room parameters go out of threshold the respective actuators will be activated and the room parameters will be brought back within threshold. The model senses five parameters like temperature, humidity, light Intensity, carbon monoxide content in air and air pressure value in the rearing room. The sensor data can also be accessed from mobile phones using MQTT application by subscribing to the topics in android phone to monitor sensor data from remote locations. The analyzation of variation of sensor data has been done for 10 days and the actuations have been carried out. Carbon monoxide sensor and Air pressure sensors have been tested as prototypes. The model has been tested on bivoltine breed of silkworms. The parameters to be maintained varies for different breeds of silkworms. Automation helps in reduction of infections to both worms and laborers and also aids in increasing the yield.

As part of future workan automated system can be tried out on different breeds throughout the entire cycle of worms and yield could be monitored. More sensor parameters could be added for effective environmental parameters maintenance.

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