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A Smart Climatic Control Strategy for Optimizing Vegetable Crop Cultivation in Greenhouse using FBANN

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Abstract

Greenhouses are designed to provide the desired climatic condition for the growth of certain plants to obtain better yield. Most of the greenhouses are developed with adequate windows that allows the natural air to reach the plants to maintain the ideal temperature. The windows are usually operated manually by verifying the greenhouse temperature and the surrounding temperature. In a few cases, the manual operations are extended to control the natural light levels and the humidity inside the greenhouse. In order to improve the performances of such climatic control in a greenhouse, certain automatic systems were developed in recent years. In the proposed work, the operations are controlled using a microcontroller module and a sensor unit. The information collected from the sensors placed inside and outside the greenhouse is forwarded to a feedback gained Artificial Neural Network (FBANN) for making the desirable operation on window and light control modules. The performances of the proposed work is verified with RMSE values observed from the manually operated controller.

Keywords: Greenhouse optimization, climatic control, back-propagation ANN, crop yield improvement.

1. Introduction

Agriculture is one of the oldest and essential occupation for human survival. The ancient agriculture requires a lot of human efforts and plenty of water. Due to the advancement of technologies and inventions, the efforts put by humans are reduced to certain extent. In the

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beginning, certain stone, wood and metal tools were invented to ease up the preparation of soil in the agriculture process. Later, the cattle were used for the soil preparation work [1, 2]. In the recent years, variety of machines like tractors and other vehicles are used for ploughing. Therefore the human efforts are getting reduced day by day in the farming process. The technology advancements and researches are expanding to automate such machines and tractor driving works with an automated software and robotic algorithms [3, 4].

Nowadays, several Internet of Things (IoT) based systems are also equipped in agriculture fields to monitor the field and crop conditions from a remote place. The IoT modules with control architectures have the ability to switch ON and OFF the water pumps located in the fields at the desired time [5, 6]. Similarly in some cases, the water pumping process is also fully automated by analysing the water content in the crop fields and soils. These kind of systems are implemented with the help of sensor unit, processing unit and control unit. The automated systems are usually made with an algorithmic statement to make a desired change in the process with respect to the threshold values observed by the sensors [7, 8].

The artificial intelligence based automated systems are developed in recent years for achieving a better efficiency in the operation. In such cases, the neural network algorithms are trained and placed in a microcontroller unit for observing the sensor readings continuously [9, 10]. At the same time, the output layers placed in the neural network algorithms are prepared to do multiple actions depending upon the minor changes observed from the sensor values. This will regulate the water dispensing work and other processes of agriculture fields in an efficient manner than the regular automated systems [11, 12].

Greenhouses are developed with wall and transparent rooftop structure to regulate the ventilation, temperature, lighting and carbon dioxide enrichment required for certain vegetable, fruits and flower plants. By regulating the lighting and temperature in the greenhouses, the crop yields are improved significantly [13, 14]. The amount of temperature, lighting and other factors to be maintained in the greenhouses are determined by various researchers. Figure 1 indicates the temperature requirement of certain vegetable and fruit crops at various stages of

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their development. The growth of crops mentioned in the figure 1 requires various climatic conditions like hot, warm, semi-cool and cold. Therefore it is difficult to cultivate such plants on regular fields. Each plant requires independent soil nature and climatic conditions too. By implementing the greenhouse kind of architecture these things can be attained in any area. The soil nature can be changed periodically inside the greenhouse for a particular crop. The temperature, ventilation and lighting control systems implemented in the greenhouses are also helpful in regulating the climatic changes [15, 16].

In the traditional greenhouses all such operations are carried out with an analog temperature monitor. Later, certain sensor based monitoring systems were developed to observe the temperature and other changes inside the various areas of greenhouses [17] so that the ventilation and lighting can be controlled independently on each side of the greenhouse. The recent advancements in technology allows to carry the changes observed by the sensors in an algorithmic tool for data mining process. The analysis made by the data mining algorithms has the ability to produce more accurate and minor changes to the operation of control units which results in an efficient climatic control process [18, 19].

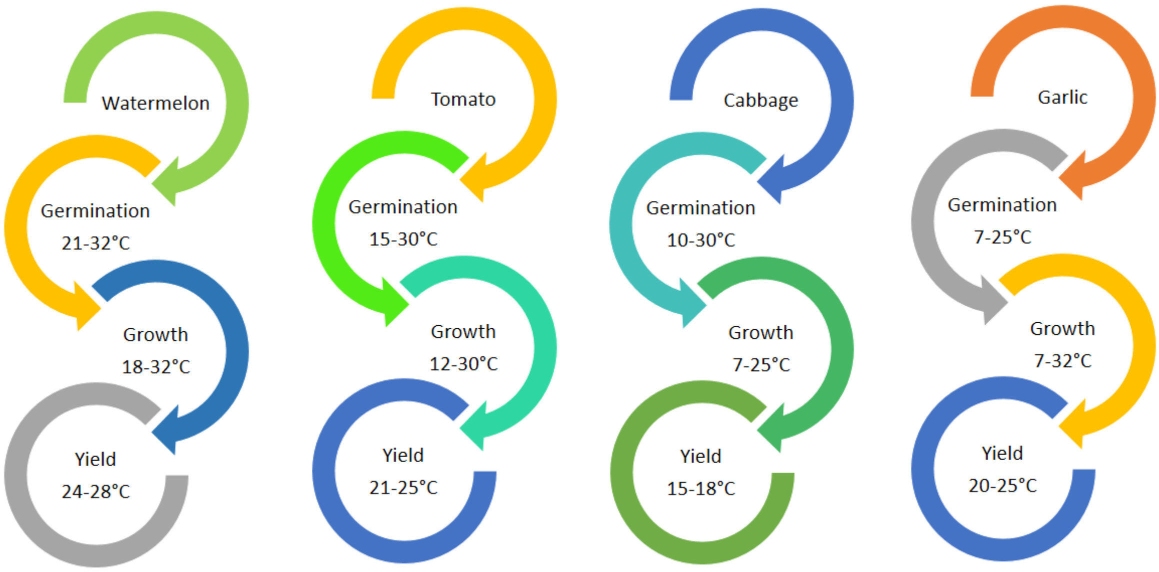

Figure 1. Temperature requirement of crops at different stages

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2. Related Work

The sensor units used in greenhouse applications are made of wireless architecture for the transmission process that are usually cost effective. Therefore a simple transmission unit with the help of an arduino or raspberry pi is always present with sensor modules. An efficient routing algorithm was also included in the microcontroller for improving the data transmission rate [20]. A data encapsulation technique based on XML was developed to improve the interoperability in a greenhouse environment. The technique acts like a multi-agent system for summarizing the data information collected from various sensors. The experimental analysis indicates the data loss rate as 1.52% from the source to the gateway communication [21]. An automatic irrigation system based on solar power backup was designed to save the energy and time required for water dispensing process. The system was also implemented with an intrusion detection system for identifying the animal and birds movement inside the field. The intrusion detection system was further extended with a Wi-Fi network for making communication to the farmer at critical times [22].

An intelligent temperature monitoring and control system was proposed, based on Petri network algorithm for determining a suitable reference temperature in a greenhouse environment. The data collected from the sensor units were also gathered in the proposed work with an energy efficient algorithm for future data analysis process [23]. The energy efficiency of data transmission was improved in certain cases by implementing a routing algorithm to transfer limited number of information per minute from the sensor nodes. Such limited number of transmission reduces the information drop rate ratio and improves the network life time. The minimization of information drop improved the precision on monitoring process [24]. A drip irrigation management system was designed with the help of IoT sensors to monitor the soil moisture and evapotranspiration. The measured values were transmitted to an IoT framework through raspberry pi controller for analysis and display purpose. An autoregressive with external input model was employed in the work for predicting the required soil moisture in the

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field. The experimental work showed betterment in the yield on comparing the analysis made by an autoregressive moving average with external input model [25].

Cloud and fog computing algorithms are developed in recent years to make the complex computational process in a remote place with lot of heavy hardware modules. So the huge data collected from the base stations are transmitted to such places through internet. To improve the security in such data transmission, the informations are usually encrypted from the base station. The cloud and fog computing algorithms are generally built up with an independent machine learning algorithm suitable for all kinds of prediction analysis. In few cases, a customized machine learning algorithm is kept over the cloud architecture for attaining a better prediction accuracy [26]. A LoRa network interface was employed in an agriculture monitoring and management system for avoiding failures in the network data transmission. The system had a secure private network for making communication between the collected data signals to the cloud environment. The system was created with a gateway topology for removing the drawbacks behind the routers modules [27].

FarmFox, an enhanced IoT module was proposed to transmit the collected information about the soil health status to the user in a remote place. The system was equipped with an arduino based hardware module which observes the turbidity and pH level of the soil located in the agriculture field. A remote processing layer was placed next to the observation layer for computation process where the collected data were analysed with a customized data aggregation algorithm. The application layer framework was designed to project the estimations in a graphical view [28]. Greenhouses are obtaining 50% more yield than the regulation cultivation method. However, the maintenance and operating cost of greenhouses are very large when comparing to the regular open air cultivation method. In order to save more money in the operation of greenhouses several IoT based controlling algorithms are introduced. In most of the cases the modules are connected to observe the temperature, CO_2 and humidity inside the greenhouse architecture [29].

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An IoT based control system was designed to get more yield in the chrysanthemum cut flowers cultivation. The system was made with a fan control unit for regularizing the temperature changes inside the greenhouse prototype and the system was also engaged with a drip irrigation setup for maintaining enough soil moisture to the greenhouse field. The experimental work reported that the growth rate of the flowers increased to 7 days in advance [30]. A multivariate convolutional long short term memory network was developed to predict the required temperature in a greenhouse field. The system was designed to observe certain information from the greenhouse field like air temperature, soil temperature, soil moisture and air humidity. The information about the wind directions are observed from a web data for the analysis work. The data collected from the sensors and web information are pre-processed at first before feeding it to the neural network algorithm [31].

The observation from the literature work explores that a reliable sensor unit with an efficient data transmission algorithm is a primary need for a greenhouse environment observation. The control process, requires an independent prediction algorithm for estimating the amount of temperature to be maintained inside the greenhouse. Many greenhouses are found with operative windows and fan units that allows the external air to cool-up the greenhouse in critical conditions. Similarly the soil temperatures are mostly maintained by a drip irrigation system controlled according to the estimations of the prediction algorithm. Based on the gathered observation, a cost efficient climatic control algorithm is developed in the proposal by implementing feedback ANN for the analysis and prediction work.

3. Proposed Work

The architectural view of the proposed work is shown in Figure 2. The proposed greenhouse management system has a sensor unit, processing unit and a control unit. The sensor unit acts as an input device for the processing unit to take several decisions on the control unit operation. The temperature sensors are used to observe the temperature inside the greenhouse and the external temperature on various locations. Similarly, the humidity values

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are also observed from environment and few places inside the greenhouse. All the sensors are connected to an arduino board for transmitting the measured readings to the microcontroller for analysis and prediction.

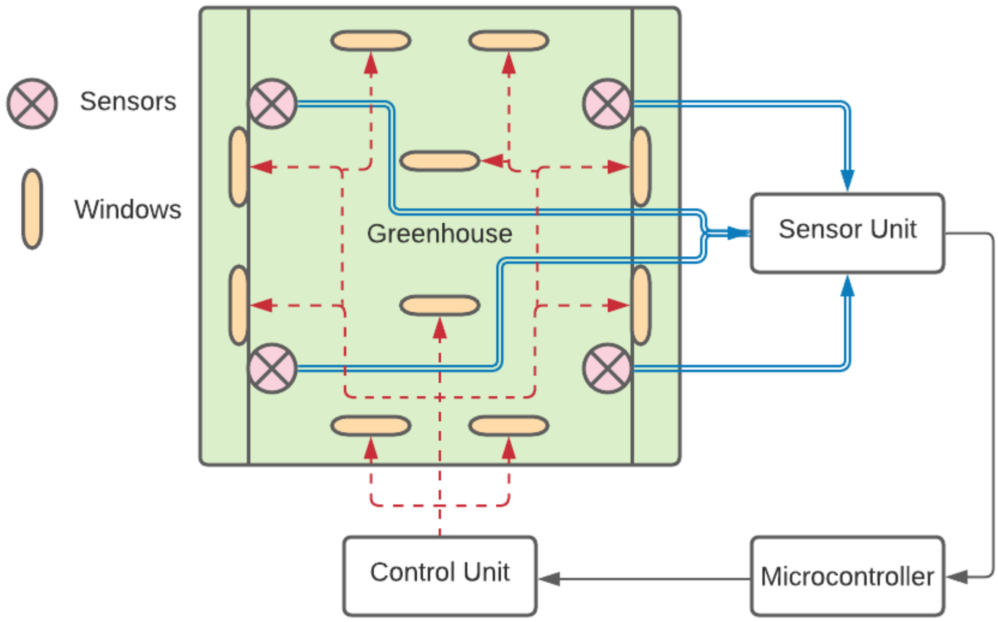

Figure 2. Architectural view of the proposed model

The extent of window to be opened or closed are also taken into account as a controllable input by the microcontroller. All the windows are operated with a control unit consisting of motors with relay module for changing the open and close position. The extent of window to be kept in open or close position is determined with respect to the algorithmic analysis made in the microcontroller unit. The microcontroller unit takes the current temperature as a feedback for analysing the extent of window to be opened for air circulation to maintain the desired temperature. The greenhouse is also made with few light shield units to its top for controlling the light interference from the natural source to the plant fields. The Light Dependent Resistor (LDR) units are employed in the work as sensing device for observing the change in light inside the greenhouse.

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3.1 Feedback Artificial Neural Networks

The Feedback Artificial Neural Network (FB-ANN) is employed in the work as a prediction algorithm in the microcontroller. Figure 3 indicates the architecture of the utilized FB-ANN algorithm. The values observed by the sensors, the current open status of the windows and the light shields are forwarded to the input layer of the algorithm along with the required temperature, humidity and the lighting lumens inside the greenhouse. All these information are forwarded to the output layer to analyse with respect to the biological neurons available in the hidden layer. The information available in each input attributes are transmitted to an individual neuron available in the hidden layer. Therefore each neuron contributes its part in obtaining the desired temperature, humidity and lighting lumens to the output layer. The accuracy of prediction is also considered in the work for analysis in the hidden layer as feedback to do fine tuning in the neuron estimations. By obtaining the feedback from the output layer, the proposed concept attains better accuracy than the other traditional neural networks.

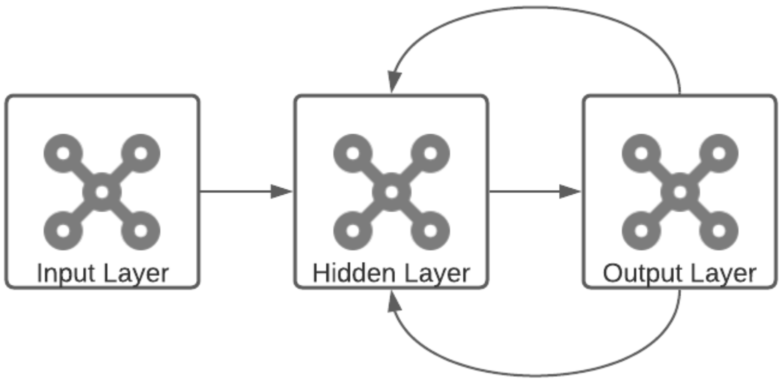

Figure 3. Architecture of FBANN

The training process of the proposed work is employed with a self-made dataset consisting of several temperature, humidity and lighting values with the extent of window, fan, light shield and lights enabled to maintain the desired temperature and light inside the greenhouse. The dataset is specially made for tomato greenhouse field for maintaining the light

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lumens of 2000 in the day time and the temperature of 15 to 30°C in the germination time, 12-30°C on growth period and 21-25°C on yielding condition. The work is also further extended to maintain the humidity of 80 to 90% in the day time and 65 to 75% in the night time for obtaining a better growth period.

4. Experimental Analysis

The temperature inside the greenhouse is maintained with a cooling fan unit. It is placed near the window for air circulation from the atmosphere. The windows near the cooling fan are operated with respect to the temperature available outside the greenhouse. The desired temperature is set with consideration to the growing stage of the tomato plant. In the present study, the desired temperature is fixed at 23°C and the observations attained by the proposed model is shown in Figure 4.

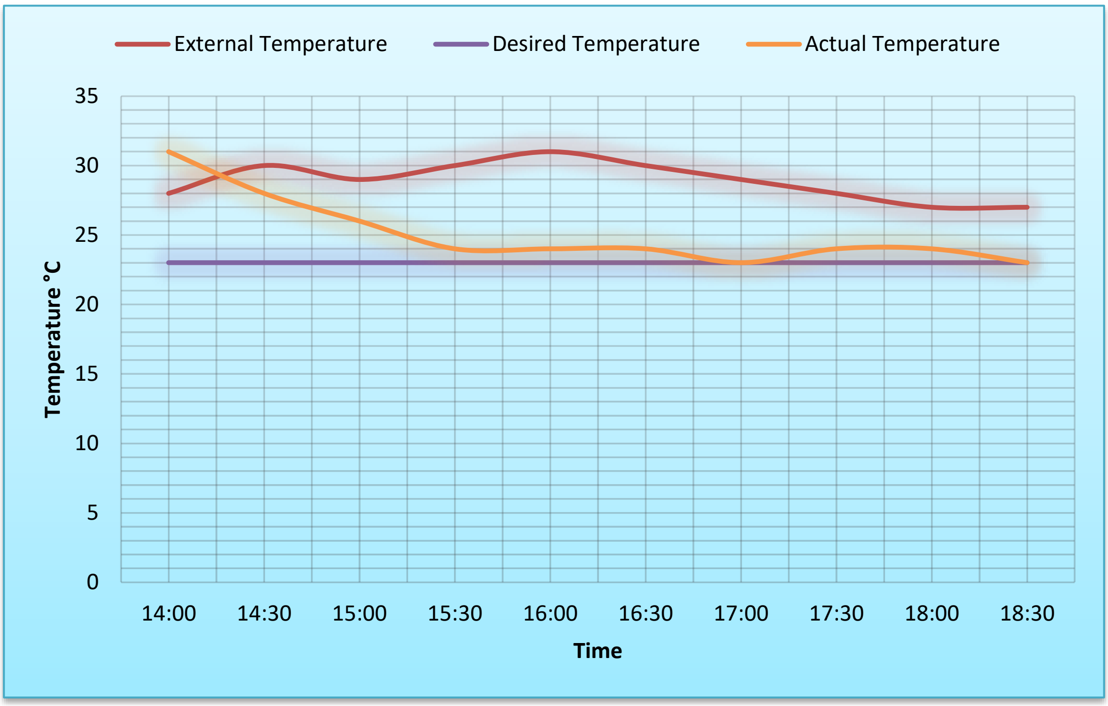

Figure 4. Temperature control performances inside the greenhouse

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The humidity value required for a tomato plant to grow ideally is 60%. The external and uncontrolled internal humidity ranges from 60 to 66%. The proposed control system model with feedback ANN reduces the humidity level from 60 to 63%. The humidity values are controlled by operating a water dispenser unit with window open close condition. The change in performances of the humidity inside the greenhouse is shown in Figure 5.

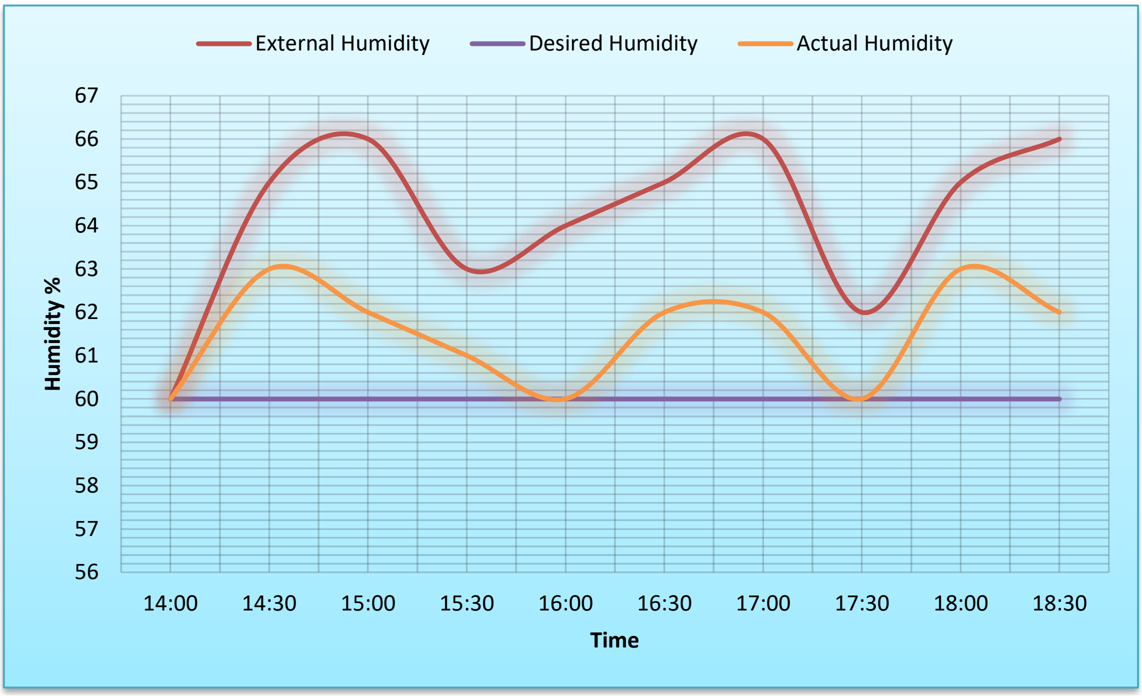

Figure 5. Performances of humidity control inside the greenhouse

The light lumens presence inside the greenhouse plays a major role in the growth of tomato plant. The optimum value of lumens required for tomato plant greenhouse varies from 6000 to 7000 lumens. The external lumens varies from 8500 to 5150 lumens on a normal day (14:00 to 18:30 hours). The desired value of lumen is specified as 6500 lumens in the algorithm. Therefore the control units connected with the microcontroller are aimed to control the light entry by modifying the light shield open close status. The light lumens are also controlled with the help of several LED lamps connected inside the greenhouse field. The change in light lumens observed from the proposed control system is explored in Figure 6.

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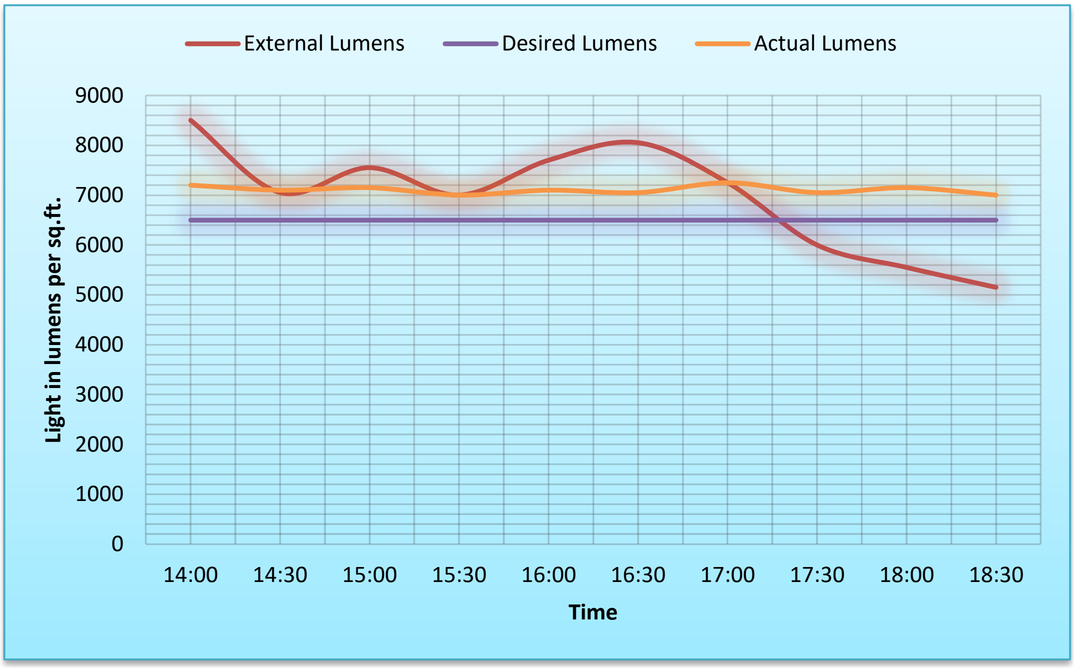

Figure 6. Observation of lumens control by the proposed system

Table 1. Effectiveness of the proposed model on full plant growth stage

Tomato plant growing stages	Actual stages attaining (days)	Stages attained without control system (days)	Stages attained by proposed method (days)
Early growth	25-30	30-35	28-33
Vegetative	20-25	25-30	20-25
Flowering	20-30	18-28	20-25
Fruit formation	20-30	25-35	25-30
Mature fruiting	15-20	15-20	15-18
Average days for full growth	118	130	120

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Table 1 represents the day count taken by the tomato plant on different growing stages with the proposed control system. It also compares the growing days of the proposed control system to the actual growth days of the plants inside greenhouse without the control system. The comparison work explores that the yield attained by the proposed system is comparatively better to the yield attained by the greenhouse without proposed system. The attainment of the proposed system is that, the average growth days computed is found to be identical to the actual growth days in each stage.

5. Conclusion

Greenhouses are designed to grow crops in a closed environment by maintaining an optimum climatic condition. The proposed system employs a digital control unit for controlling various hardware modules like window, light shield, fan, light and water dispenser available inside the greenhouse. The amount of control signal required to operate the hardware modules are computed by a trained feedback artificial neural network algorithm. The actual average plant growth days is compared to the average plant growth days attained by the proposed control system and the performances are evaluated. The experimental analysis indicates that the proposed work achieves a better growth rate than the greenhouse plants without control system. The individual observation of the proposed system on the temperature, humidity and light adjustments are found to have a significant advancement.

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