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Effective Greenhouse Monitoring and Controlling Using Recurrent Fuzzy Neural Network

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Abstract: Greenhouse is an artificial environment where parameters like soil moisture, temperature, humidity and light intensity are monitored and controlled for the proper development of crops. Monitoring and controlling of crops can be improved by using the technologies like IoT and fuzzy logic. This study presents architecture of a greenhouse monitoring and controlling system using a cooperative neuro-fuzzy system where self organizing map is used to extract optimal rules from a recurrent fuzzy neural network. The study describes the way in which data is captured from the sensors related to greenhouse environmental conditions by using the concept of IoT and the learned fuzzy system is used to analyze and make effective decisions.

Key words: Greenhouse monitoring, IoT, neuro-fuzzy system, fuzzy controller, neural network, environment

INTRODUCTION

Indian economy is majorly driven by agriculture sector. Nearly 70% of Indian population depends on agriculture for their livelihood. Thus, there is need to improve the technical aspects of agriculture for efficient production of crops. In order to optimize crop growth, there was a need for automatic control systems to have maximum crop yield and minimum cost. Lees *et al*. (1996), Tap (2000) and Hanan (1998) have developed various control techniques such as conventional, classic, artificial intelligence, advanced control techniques, robust control techniques which have been applied in area of greenhouse monitoring systems.

Conventional techniques are difficult to implement due to their multi variable and non-linear nature. Thus, this gives a good justification to use an intelligent control technique. A fuzzy logic implemented using artificial intelligence can develop an intelligent control system (Lee, 1990). The use of IoT in the greenhouse monitoring and controlling system is the integration of sensing technology, network technology and intelligent control technique to facilitate actuators (Huircan *et al*., 2010; Collier *et al*., 2010; Riquelme *et al*., 2009).

With the implementation of greenhouse system, the agricultural production will produce lot of complex information (Cui, 2011). Thus, intelligent systems (Zheng *et al*., 2010; He, 2012; Hori *et al*., 2010) are required to manage the complex information, moreover, the greenhouse data requires lot of analysis, processing and decision making which makes cloud/server very important for implementation of greenhouse system.

This study proposes an idea to monitor and control the greenhouse conditions for proper development of crop with the help of IoT technology and fuzzy control system using a cloud/server technology.

This model captures parameters like temperature, humidity, soil moisture and intensity of light through the help of various sensors connected to the Raspberry Pi. A cooperative Neuro-Fuzzy System is used to extract optimal rules to built the rule base. A recurrent neural network is used with fuzzy weights and biases as adjustable parameters. Internal feedback loops allow it to capture dynamic response of the greenhouse controlling system without using external feedback through delays. All the nodes of Fuzzy Recurrent Neural Network (FRNN) are able to process linguistic information. Self Organizing Map (SOM) is used for the learning of FRNN.

MATERIALS AND METHODS

Existing systems: Previously, there exist the systems which uses the models like ZigBee based, microcontroller based, IoT based models which captures the greenhouse data from the various sensors and take the decisions based on the certain threshold values. According to these threshold value actuators gets activated either manually or by automated system. There also exists system

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(Thenmozhi *et al*., 2014) in which control certain environment variable like temperature or soil moisture and perform actions based on that. Some of the major greenhouse monitoring and controlling systems are define.

There exist an IoT based crop monitoring and controlling system to monitor crop-field using sensors (soil moisture, temperature, humidity, light) and automate the irrigation system. The data from sensors are sent to web server database using wireless transmission. In server database, the data are encoded in JSON format. The irrigation is automated if the moisture and temperature of the field falls below the brink. In greenhouses, light intensity control can also be automated in addition to irrigation. The notifications are sent to farmer's mobile periodically. The farmer's can able to monitor the field conditions from anywhere. This system will be more useful in areas where water is in scarce (Rajalakshmi and Mahalakshmi, 2016).

In fuzzy based temperature control of greenhouse (Revathi and Sivakumaran, 2016), the temperature of the greenhouse is monitored from the temperature sensor and this data is sent to the fuzzy logic control the error is calculated and process is repeated again with the new values. Based on the result of the fuzzy logic control suitable actions were taken to maintain the temperature of the greenhouse environment.

Using wireless sensor networking precision farming can be achieved when implemented in greenhouse environment. Wireless sensor network removes lack of measured data based on which certain actions are taken at the time when there is need to maintain the suitable environment. After measuring and accumulating data, the guess work can be removed and then certain decisions like turning ON/OFF actuators can be taken easily. With the implementation of wireless sensor networking, greenhouse environment can be accessed by farmers anywhere over cloud using web or Android App. Based on the real-time values obtained from various greenhouse chambers over period of time various reports can be plugged as studied in detail by Kim *et al*. (2015), Singh and Sharma (2015), Zaslavsky *et al*. (2013) and Singh *et al*. (2015).

Using GSM and wireless sensor technique. In this system, the data is collected by the wireless sensor node and then, it is optimized using the fuzzy logic to optimize the water usage. It is implemented using the ArduinoUNO board. This system also checks the health of the plant by checking its leave using the image processing technique. The data is regularly monitored against the various environmental parameter and then, the health of the plant is judged. By judging these condition, the farmer can control the environment remotely using the Android application (Geetha and Priya, 2016).

Fuzzy logic control has been considered for intelligence control. It is technique for design a robust system that can contained with the common factors such as nonlinear parameters, uncertain measurements. Fuzzy logic controller has human decision making. Fuzzy logic control has been widely used in industrial process control and control performance in accuracy, good response, robustness and stability. Fuzzy control system implementation is based on three phases those are, i.e., calculate the membership value (also called as fuzzy sets) create the rule table and defuzzifying the result (Shankar, 2014).

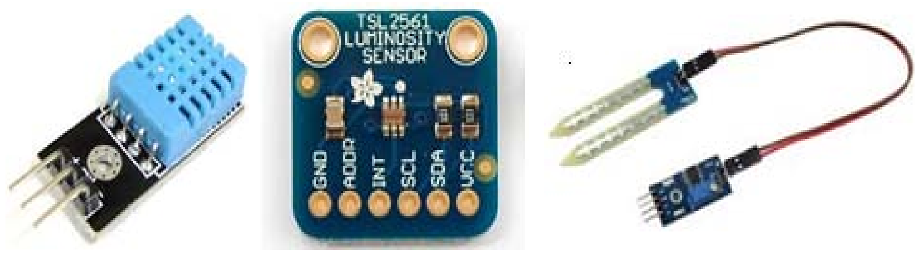
RESULTS AND DISCUSSION

Proposed system: Proposed system uses the concept of both of these kinds of system. It uses the IoT technology to capture the data from the environment variable like humidity, temperature, soil moisture and light intensity and it uses the fuzzy logic control system to make decisions. Where, the rules are extracted by SOM from FRNN.

The system comprises of a credit card sized computer called the Raspberry Pi with 4 sensors connected to the system such as soil moisture, light intensity, temperature and humidity. The sensor constantly monitors the greenhouse conditions and sends the data in JSON file format in regular time intervals to the online server. The rule base has been defined on the server for the decision making. The web and the Android App. is used to display the data and triggers the notification based on the decision made by the fuzzy control system.

The Raspberry Pi consists of 40 GPIO (General Purpose Input Output) pins, 4 USB ports, quad-core processor with 1 GB ram along with various useful ports and interfaces. It runs on the supply of 5 V. Figure 1 shows the Raspberry Pi 2 Model B used in the project to serve the purpose.

Fig. 1: Raspberry Pi 2 kit Model B



(a) (b) (c)

Fig. 2: a) Humidity and temperature sensor; b) Light sensor and c) Soil moisture sensor

Humidity sensor also called as hygrometer measures and regularly reports the related humidity in the air. There are various ranges of humidity and temperature sensors like HS1100, HHH10D, HR 202, HSM 20, DHT 11, etc. The DHT 11 temperature and humidity sensor used in the project (Fig. 2a) features a temperature and humidity sensor complex with a calibrated digital signal output. This sensor includes resistive type humidity measurement component and an NTC temperature measurement component.

Light sensor is a device used to detect light. There are different types of light sensors each of which works differently. A photo resistor is a small sensor that changes its resistance when light shined on it. These are used in many consumer products to determine the intensity of light. A charged couple device transports electrically charged signals and is used as a light sensor in digital cameras and night vision devices. Photomultipliers detect light and multiply it, e.g., TSL261. Figure 2b shows the light sensor used in the project.

In the context of water management for irrigation, measuring and monitoring soil water status is an essential component of Best Management Practices (BMPs) to improve the sustainability of agriculture. Water content in the soil can be directly determined using the difference in weight before and after drying a soil sample. This direct technique is usually referred to as the thermo-gravimetric method (or simply gravimetric) when expressing water content as weight of water over weight of dry soil, GWC (lb3lb-3) (i.e., the ratio of the mass of water present in a sample to the mass of the soil sample after it has been oven-dried (100-110°C) to a constant weight). On the other hand, the thermo-volumetric method (or simply volumetric) gives the water content as volume of water in a volume of undisturbed soil VWC, i.e., volume of water related to the volume of an oven-dried undisturbed sample. Figure 2c shows the soil moisture sensor used in the project.

In the last decade, the fuzzy logic gained interest in the scientific community and fuzzy knowledge-based systems are one of the most successful applications of fuzzy sets and fuzzy logic methods. This is mainly due to the flexibility and simplicity by which knowledge can be expressed using fuzzy rules as well as to the theoretical developments in this field.

The main advantage of fuzzy control is the possibility of implementing human expert knowledge in the form of linguistic if then rules. The design of a fuzzy controller begins with the choice of linguistic variables, the process state, the input and the output variables. The next step is the choice of the set of linguistic rules and the kind of fuzzy reasoning process. Once the rules are setup, after the inference, the fuzzy set and the crisp output value have to be generated; a de-fuzzification strategy has to be established too.

In rule base, rules for taking the decision based on the greenhouse conditions are defined. In this system, there are 4 sensors if each sensor's data is defined using n fuzzy functions and we have m fuzzy functions to define notifications then, there will be total of n4m rules. Rules are defined as:

- If temperature is n1 and humidity is n1 and soil moisture is n1 and light intensity is n1 then generate notification m1
- If temperature is n2 and humidity is n2 and soil moisture is n1 and light intensity is n2 then generate notification m2
- If temperature is n2 and humidity is n1 and soil moisture is n3 and light intensity is n2 then generate notification m3

SOM is used for learning of the recurrent fuzzy neural network. The network layers take all the possible rules which could be generated for the captured data. In hidden layer rules are applied on fuzzy values. Input layer has 16 nodes and the output layer has 4 nodes.

Figure 3 shows the working of the complete system. Here, the sensors are used to capture the data and they interact with the Raspberry Pi kit sends the data captured by the sensors to the server. The notifications are generated on the Android and web App. based on the decision made by the server.

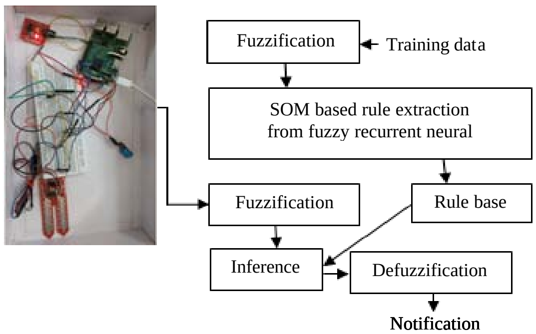


Fig. 3: Working of proposed green house monitoring and controlling system

Training data contained 220 random samples. Four triangular fuzzy functions (low, medium, high, very high) were defined for each sensor data. Notifications are generated for each sensor based on the inference. SOM based learning of the RFNN resulted in only 11 rules. The Mean Squared Error (MSE) obtained is 0.0053.

CONCLUSION

This study focuses on developing an effective greenhouse monitoring and controlling system that will eliminate the problem of greenhouse monitoring providing a better and effective notification system. Fuzzy logic based control system are more effective whenever there is any uncertainty in the environment. Environmental uncertainties always exist that affect the controlling of greenhouses. Recurrent fuzzy neural networks are very effective in modelling such dynamic systems. Rules are extracted using SOM from a RFNN used to model the greenhouse controlling system. Once, the rules are extracted then, the fuzzy control system with optimal rule base is used to generate appropriate notifications based on continuous data obtained from the four sensors. The proposed system resulted in 0.0053 MSE on the utilized dataset.

RECOMMENDATIONS

In future, we are planning to prepare a real dataset by consulting an expert and test the proposed system in a real environment. Further, to improve the efficiency, a weather prediction system is to be incorporated in decision making.

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