Design of Android Base Fuzzy Wireless Sensor Network for mini Smart Green House

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Abstract: This article presents a mini smart greenhouse climate control using Wireless Sensor Networks (WSNs), and Android phone supporting android applications and a system for plant realtime monitoring. In this system the optimized data are collected from the wireless sensor nodes and then the data are analyzed for an expert climate control using fuzzy logic in order to optimize water usage and energy consumption. The fuzzy logic parameter is used and implemented using Arduino board. The data from different sensors are aggregated to repeatedly monitor temperature, humidity, soil moisture, light intensity in the greenhouse. The information from the greenhouse climate is received by the sensor node, it is transmitted to the wireless node through a wireless protocol. This system uses nodemCu wireless module for data transmission from the end devices to the web server node. With the information from the web server node the farmer can monitor and control the greenhouse climate automatically using android application.

1. Introduction

Through A greenhouse climate is its own little ecosystem, entirely dependent upon the farmer. The farmer decide how much water, nutrients, sun and other elements your plants receive. To ensure farmer’s indoor garden never misses out, farmer can automate the process. Commercial growers have been working with automatic systems for years. Now the technology has been standardized and scaled down to suit most greenhouse situations.

It is now possible to select from a range of monitoring systems to create the ideal climate for your greenhouse and the ideal habitat for the plants. Monitors for temperature and humidity are basic. Additional monitors can check on soil moisture and soil acidity.

This propose technology is easy-to-use and easy-to-install. It comes with remote Internet access which makes it easy to check up on the crops when the farmers are away from their greenhouse operation. Imagine keeping an eye on the internal greenhouse climate and crop feed all from the smartphone. This Greenhouse Automation Systems work around the clock to optimize the greenhouse climate, increase crop yields, reduce energy costs as well as labor costs. The systems protect the entire greenhouse against harsh weather conditions and immediately notify the farmer with an alarm should something go awry, giving you the freedom to not have to monitor the greenhouse at all times yourself.

Wireless Sensor Network (WSN) is a collection of sensor and actuators nodes linked by a wireless medium to perform distributed sensing and acting tasks. The sensor nodes collect data and communicate over a network environment to a computer system, which is called, a base station. Based on the
information collected, the base station takes decisions and then the actuator nodes perform appropriate actions upon the environment. This process allows users to sense and control the environment from anywhere. There are many situations in which the application of the WSN is preferred, for instance, environment monitoring, product quality monitoring, and others where supervision of big areas is necessary. [1]

An Embedded systems approach to Monitor Green House is an approach to measure parameters in the Green house. They have designed a system consists of sensor circuits, PIC microcontroller, RS 232 serial communication, LCD module to display the parameters, GSM modem to update user, mobile receiver, and required power supply unit. The output of the sensors is given to the microcontroller to control, display the parameters and update the owner. Any parameter changing with set parameter for Green House systems, the microcontroller will read and stores periodically, in turn it updates the user by sending SMS by service provider. The program is written in microchip’s MPLAB IDE 8.4. [2]

Wireless sensors are tiny devices that are able to measure several environmental and crucial data. Recently, these devices have been used in areas such as environmental monitoring, home automation, and war scenarios. In this context, a new emerging technology called wireless sensor networks (WSNs) has become a trend in technological research [3,4]. This technology combines hundreds or even thousands of tiny and resource constrained sensor devices that communicate wirelessly in order to accomplish a common task. These devices are spatially distributed in the environment in order to collect data about surrounding environmental variables [5,6]. Each device has several sensor modules capable of measuring parameters such as temperature, humidity, and luminosity.

The proposed system consists of The input of the system, they are sensor scale, and the output of the system are actuators scale. The sensor DHT-11, soil moisture sensor, and LDR sensor. Node MCU is a microcontroller that process sensor value and then respond to the actuators.

Actuators at the System are booster pulp for irrigation, fan for to cool the greenhouse rim, and the lamp to light the room.

2. Experimental Details

2.1. Fuzzy Logic Control

The role of the greenhouse in protected cultivation is to provide optimal microclimate conditions for plant growth. From the systems theory aspect, protected food cultivation in greenhouses represents a complex nonlinear system, including number of subsystems emphasized variables interdependency [7]. Basically, the main controlled variables are: Temperature, Humidity, Soil moisture, Light Intensity.

Fuzzy logic [8], [9], [10] is mathematical theory dealing with uncertainty. This approach is widely used in modeling nonlinear systems with high complexity, plant dynamics is unknown or it can change rapidly. This approach is intuitive, input and output variables are linguistically described, and design of control algorithm is primarily based on if-then-else rules. Fuzzy Logic Controllers are widely used in different engineering areas [9], [10] including Artificial Intelligent, Expert systems, Robotics and Biotechnology. There are few researches in applying this promising method into control of greenhouses [11], [12]. The main unit of the Fuzzy Logic Controller is Fuzzy Inference system (FIS). The FIS consist of five processing parts:

- Fuzzification interface which generates linguistic variables based on crisp data inputs from sensor subsystem
- Defuzzification interface which generates crisp control output to the actuators
- Decision making unit, based on predefined control logic, generates inference operations
- Database process provides the fuzzy sets and membership functions used in fuzzy rules
- Rule base unit consisting of an adequate number of fuzzy rules

In the presented system input (sensor) variables are: Humidity (%) (Fig. 1), Soil Moisture (%) (Fig. 2), Temperature (°C) (Fig. 3), and Light Intensity (Lux) (Fig. 4).
Figure 1. Humidity membership function (%)

Figure 2. Soil Moisture membership function (%)

Figure 3. Temperature membership function (°C)

Figure 4. Light Intensity membership function (Lux)

Output (Actuator) variables are: Irrigation (sec) (Fig. 5), Cooling (sec) (Fig. 6), and Heating (sec) (Fig. 7)

Table 1. Fuzzy Rule for irrigation

| Temperature | cool | Normal | hot |
|-------------|------|--------|-----|
| Humidity    |      |        |     |
| Dry         | medium | medium | Long-time |
| Normal      | medium | medium | Long-time |
| Moist       | off   | off    | off |

Table 2. Fuzzy Rule for cooling

| Temperature | cool | Normal | hot |
|-------------|------|--------|-----|
| Soil        |      |        |     |
| Moisture    |      |        |     |

Presented FIS for Greenhouse control executes three actions, First process of fuzzification (conversion of crisp values from sensors) into linguistic variables within predefined fuzzy sets. Then, rule base unit based from the knowledge database generates control strategy, and third action is defuzzification where crisp outputs are generated for actuators.

- Rules
| Dry     | Off | medium | Long-time |
|---------|-----|--------|-----------|
| Normal  | Off | medium | Long-time |
| Moist   | Off | medium | Long-time |

Table 3. Fuzzy Rule for heating

| Light Intensity | dingin | Normal2 | Panas |
|-----------------|--------|---------|-------|
| Dark            | medium | medium  | Long-time |
| Normal          | medium | medium  | Long-time |
| light           | Off    | Off     | Off   |

If The humidity is 72 % and temperatur is 30º ?

- The humidity is 72 % at membership function normal and moist
  \[ \mu \text{ normal humidity}[x] = \frac{75 - 72}{75 - 60} = \frac{3}{5} = 0.6 \]
  \[ \mu \text{ moist humidity}[x] = \frac{72 - 60}{75 - 60} = \frac{12}{5} = 2.4 \]
- The temperature is 30ºC at membership function normal and hot
  \[ \mu \text{ normal temperature}[x] = \frac{35 - 30}{35 - 28} = \frac{5}{7} = 0.714 \]
  \[ \mu \text{ Hot temperature}[x] = \frac{30 - 28}{30 - 28} = \frac{2}{7} = 0.285 \]

[R1] if The humidity is normal AND the temperatur is normal then output The irrigation is medium
\[ \alpha - \text{predicate 1} = \mu \text{ humidity normal, } \mu \text{ Temperature normal} \]
\[ = \min(0.6 ; 0.714) = 0.6 \]

The fuzzy set of normal output
\[ \frac{(20 - z1)}{(20-15)} = 0.6 \]
\[ Z1 = 20 - 0.6(20 - 15) \]
\[ Z1 = 20 - 11 \]
\[ Z1 = 9 \]

[R2] if the humidity is normal AND The temperatur hot then output The irrigation is long time
\[ \alpha - \text{predicate 2} = \mu \text{ normal humidity, } \mu \text{ Temperature hot} \]
\[ = \min(0.6 ; 0.285) = 0.285 \]

The fuzzy set of normal output
\[ \frac{(z2 - 15)}{(20-15)} = 0.285 \]
\[ Z2 = 0.285(20 - 15) + 15 \]
\[ Z1 = 1.25 + 15 \]
\[ Z1 = 16.25 \]

[R3] if the humidity is moist AND temperature normal then output The irrigation is off
\[ \alpha - \text{predicate 3} = \mu \text{ The humidity is moist, } \mu \text{ Temperature normal} \]
\[ = \min(2.4 ; 0.714) = 0.714 \]

The fuzzy set of normal output
Z3 = 0, because it's off

[R4] if the humidity is moist AND temperature hot then the irrigation’s output is off

\[ \alpha - \text{predicate} = \mu \text{ The humidity is moist, } \mu \text{ Temperature hot} \]

\[= \min(2,4 : 0,285) \]

\[= 0,285 \]

The fuzzy set of normal output

Z4 = 0, because it’s off

- Defuzzication

\[ \frac{\sum \alpha \times Z}{\sum \alpha} = \frac{(0,6 \times 9) + (0,285 \times 16,25) + 0 + 0}{0,6 + 0,285 + 0,714 + 0,285} = 7,19 \]

From Matlab, we get defuzzification’s value is 7,31, and by manual calculation is 7,19. Then we can calculate its different, we call it error.

\[ \Delta = 7,31 - 7,19 = 0,12 \]

\[ \text{Error} = \frac{0,12}{7,31} \times 100\% = 1,64\% \]

3. System Design

![Figure 8. System Block Diagram](image)

Block Diagram for Smart fuzzy Greenhouse control System is given at figure 8. The input of the system are sensor scale, and the output of the system are actuators scale. The sensor DHT-11, soil moisture sensor, and LDR sensor. Node MCU is a microcontroller that process sensor value and then respond to the actuators.

Actuators at the System are booster pulp for irrigation, fan for to cool the greenhouse rim, and the lamp to light the room.

4. Implementation

4.1. Fuzzy Node MCU testing

This fuzzy control implementation for decision support of the system. The decision used to be the output of the system according to input data from the sensors.

**Testing tools are:**

1. Node MCU Microcontroller
2. USB data Cabel
3. Arduino Software
4. Sensor DHT 11 as input
5. Relay 5
6. Water pump as output
Figure 9 show testing result of fuzzy programming

![Fuzzy Programming result](image)

**Figure 9.** Fuzzy Programming result

As example from the testing result than when humidity is 51%, and temperature is 31 ° then the water pump on for 6 secon.

4.2. **Node MCU communication testing to Web Server**

This testing is to send input data to web server, then web server send to android from web server.

The testing tools are:

1. Node MCU Microcontroller
2. USB data Cabel
3. Arduino Software
4. Sensor DHT 11, soil moisture, dan LDR as input
5. Akun at server web ubidots.com
6. internet connection

Testing’s result:

![Communication’s results from node mcu to ubidots.com](image)

**Figure 10.** Communication’s results from node mcu to ubidots.com.

5. **Conclusion**

Based A Fuzzy Wireless sensor network was successfully implemented for monitoring agricultural environmental parameters and greenhouse climate and was tested for real time. The sensed data is transmitted to the receiver station through via Internet by Android module. Receiving station converts the data into a text file and this text file is passed to the fuzzy control logic for taking controlling actions of output in the field depending on the soil moisture contents and atmospheric conditions.

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