Design of an Environmental Parameter Monitoring and Intelligent Control System for Vegetable Greenhouses Based on AT89C51 Microcontroller

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Abstract. To address the issues of low efficiency and inadequate accuracy of environmental control occasioned by the old manual management in vegetable greenhouse, the current work constitutes an intelligent vegetable greenhouse control system based on AT89C52 microcontroller. The system consists of a microcontroller that is the central component, a DHT11 temperature and humidity sensor, a light sensor with a photosensitive sensor, and MQ-135 CO_2 sensor. The ADC0832 converts analog signals in order to collect the essential data on conditions such as temperature, humidity, the level of light, and the CO_2 concentration ratio in real-time. The system operates automatic devices like heating wires, fans, and water valves to maintain good growing environment of plants using set limits. Meanwhile, information is displayed on the real-time basis on an LCD1602 display, and the control limits and mode switching are done via matrix buttons. Proteus software is utilized in the work to create a simulation platform in which to carry out testing followed by hardware-software co-debugging to check.

Keywords: Vegetable greenhouse, AT89C52 microcontroller, Environmental parameter monitoring, Automatic control, Sensor technology.

1. Introduction

Humidity and temperature play a very crucial role in the way human beings live. Ever since industrial revolution in the 18th century, the ability to make something at a factory was coupled to the ability to control temperature and humidity. With industries such as metal work, steel, oil and chemicals, cement, glass and drugs, it is about 80 percent of the industries that have to consider the temperature and humidity. One of the solutions is the green houses [1]. An artificial weather condition is created by making a greenhouse to replicate a weather that contributes to plant growth, so that the temperature restrictions on living organisms can be abandoned. Another advantage of greenhouses is the ability to surpass environmental restrictions on growth allowing farmers to produce various crops when the season is unfavorable reducing the enormous impact of seasons on crops making crops less reliant on nature [2].

Computer control systems that have automated agricultural production and administration has become a staple of modern agriculture [3]. The recent years have been characterized by an accelerated development of electronic and information technologies, which has triggered the revolution in the methods of greenhouse control and management [4].

In this paper, we start by introducing the system design framework that will include a description of the system requirements as well as the control strategies. Hardware design section is concerned with the different parts used in the system such as different electronic parts. The software design part expounds the functions and control flow logic that are in place. The final part gives the system simulation test, such as test on the control processes.

2. Conceptual design

2.1. System functional requirements

Get live watching and automatic adjustment of greenhouse conditions like temperature, humidity, light level, and CO_2 amount. It has manual or automatic mode choice, allowing automatic control of heaters, fans, water valves, and other gear based on set levels. Also, greenhouse conditions can be shown live on a screen.

The setup uses a microcontroller-based control design. Sensors like the DHT11 temperature/humidity sensor, light sensor, and CO_2 sensor keep gathering greenhouse data. After A/D change, the handled signals go to the microcontroller. Using set numbers and gathered data, the microcontroller makes logic choices to control things like heaters, fans, and water valves, while showing live numbers on the LCD screen. Also, special buttons are given for setting numbers and changing modes [5]. System architecture diagram is shown in Fig.1.

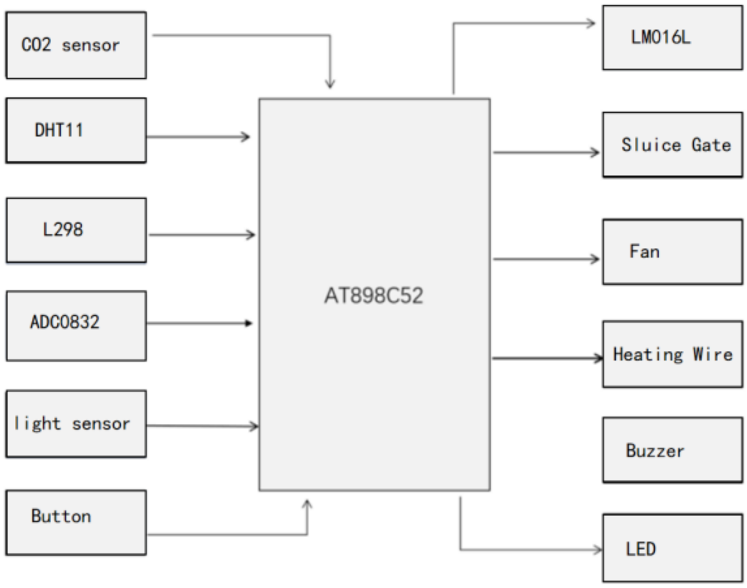

Figure 1. System architecture diagram (Picture credit: Original)

2.2. Control strategy

2.2.1. Temperature and humidity control

Set the upper and lower temperature limits suitable for vegetable growth. When the temperature inside the greenhouse falls below the lower limit, the microcontroller controls the heating wire relay to close, activating the heating wire to raise the temperature. When the temperature reaches the upper limit or exceeds a certain range, the fan is activated to accelerate air circulation and dissipate heat, maintaining the temperature within an appropriate range.

Set thresholds based on the moisture requirements of vegetables at different growth stages. When humidity falls below the lower limit, the microcontroller controls the water valve relay to close, activating the water valve for irrigation and humidification. When humidity exceeds the upper limit, the fan is activated to ventilate and reduce humidity.

2.2.2. Light control

The light sensor can monitor the light intensity in real time. When the light is insufficient, the reserved expansion interface can be used to automatically turn on the supplementary light when the light is insufficient; when the light is too strong, the shading equipment (if there is an expansion design) can be considered to adjust the shading.

2.2.3. CO_2 concentration control

Set the appropriate CO_2 concentration threshold. When the concentration is lower than the lower limit, the CO_2 can be automatically replenished by connecting the CO_2 cylinder and electromagnetic valve (reserved control interface); when the concentration is higher than the upper limit, the concentration can be reduced through ventilation

3. Hardware design

3.1. Main control unit

AT89C52 single chip microcomputer is selected, which has rich I/O interface to meet the needs of sensor data acquisition and actuator control, and abundant development resources for program writing and debugging.

3.2. Sensor module

Using DHT11 and single bus communication mode, the temperature and humidity in the greenhouse can be measured accurately in real time. The measurement range is 20-90%RH for humidity and 0-50℃ for temperature, which meets the requirements of vegetable growth environment monitoring.

The photosensitive resistor is combined with RV3 potentiometer to form a voltage divider circuit, which converts the light intensity into a voltage signal and provides the single chip microcomputer to read after A/D conversion.

The sensor of MQ-135 type is selected to convert the CO_2 concentration into voltage signal together with RV1 potentiometer, and then transmit it to the MCU after A/D conversion.

3.3. Executive module

The heating wire is controlled by the relay RL1 driven by transistor Q2. When the temperature is lower than the set value, the single chip controller controls the relay to close and the heating wire works.

The L298N motor drives the chip U3 to control the fan. When the temperature or humidity is higher than the set value, the MCU controls the fan to start ventilation.

The relay RL2 is driven by transistor Q3 to control the water valve. When the humidity is lower than the set value, the water valve opens for irrigation.

3.4. Display and button module

The LCD1602 LCD screen is used to communicate with the MCU in parallel, and display temperature, humidity, light intensity, CO_2 concentration and other parameters in real time.

The matrix keyboard is composed of several keys to achieve parameter setting, mode switching, data viewing and other functions.

4. Software design

4.1. Software architecture

Adopting modular programming philosophy, the entire program is divided into multiple functionally independent modules, which not only facilitates code writing, debugging, and maintenance, but also improves code reusability. Specifically divided into sensor data acquisition module, data processing and control module, display module, button processing module, and communication and storage module (for extended functions) [6]. The modules interact with each other through defined interfaces and work together during program execution to achieve various functions of the intelligent control system for vegetable greenhouses.

4.2. Master program flow

The function flow chart of the main program of the system is shown in Fig.2 below.

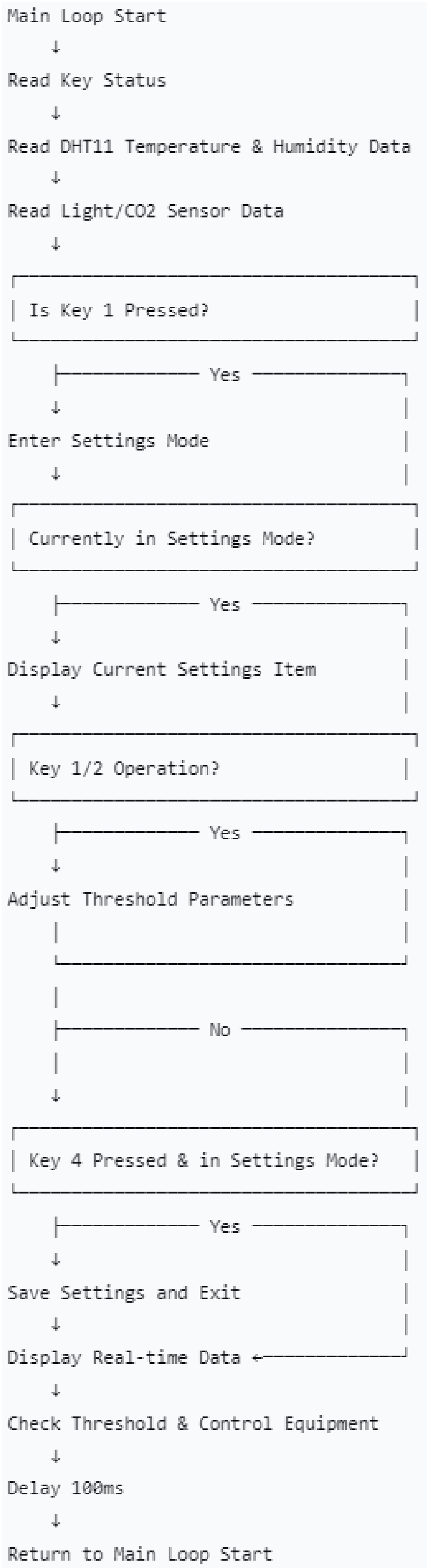

Figure 2. Master program flow (Picture credit: Original)

4.2.1. System initialization

Once the system has been started, the first set up process will consist of full configuration. In the case of microcontroller ports, relevant input/output modes are set depending on the module connections to receive the correct transmission of data and output the control signals in an effective way [7]. In the process of display startup, display mode and cursor status are configured in order to be ready to display further data. Sensor configurations are in accordance with their communication protocol: e.g., the DHT11 temperature and humidity sensor has certain parameters of single bus communication settings in order to ensure accurate data capture.

4.2.2. Data collection cycle

Once a system has been initialized, it enters an infinite loop. It starts its own cycle by calling the sensor data acquisition module, which sequentially reads the environmental parameters of temperature, humidity, light intensity, and CO_2 concentration. In order to provide accuracy in data during this process, several techniques such as averaging models over several sampling points can be used in order to reduce noise interference and accidental error.

4.2.3. Data processing and control decision making

The received data is sent to Data Processing and Control Module. In this module, filtering is done initially in order to remove possible interference signals. Control decisions are made and the processed data is compared to preset thresholds after comparison. As an illustration, when the temperature drops below the lower limit that is set up, the module sends a control signal to the microcontroller to shut the heating wire relay [8]. In case the humidity level goes higher than the upper limit set, the module will turn the fan on to provide ventilation and dehumidification of the area.

4.2.4. Data presentation

The system enables the display module to show in a standard format, processed implementation of environmental parameters and information on operational status in the LCD1602 display. To be even more comprehensive, such characteristics as split-screen display and data refresh may be introduced. It comprises of automatic updates of content at designated time intervals or dynamic page switching that is accomplished through the interaction of buttons so that the users could investigate various kinds of environmental parameters with the assistance of independent displays.

4.2.5. Key detection and processing

The system constantly checks significant states during the process of the loop. On pressing a key, the button processing module is institutionally triggered. This module identifies user inventiveness by key combinations and pressing time, and performs specific functions. As an example, when a key is long-pressed, the setting of parameters mode opens, and when it is short-pressed, pages are shown in the display or operations are confirmed.

4.3. Module function implementation

4.3.1. Sensor data acquisition module

Special drivers are prepared in the case of different sensors. As a case in point, using the DHT11 temperature and humidity sensor, the coding is provided according to its one-wire communication principles. The code begins with transmitting a start command, waiting until the sensor responds, and reading the data one bit at a time e.g. humidity whole numbers, humidity decimal parts, temperature whole numbers, and temperature decimal parts. To ensure even more reliability of data collection process, there are error handling procedures, which are somewhat built into the code, such as attempting to read again, displaying an error message in the event that the sensor has taken too long to respond, or in the event of data checks failing [9]. With light sensors and CO_2 sensors, analog voltage is converted to digital using an A/D conversion circuit. Conversion D/A converting drivers are written to obtain the correct voltage signal reading and conversion, thus the correct light level and CO_2 concentration numbers are located.

4.3.2. Data processing and control module

Once sensor information has been received, it is then filtered with a filter such as the median filtering or weighted average filtering to remove noise. The data obtained after the cleaning process is verified against established limits that can be modified according to the requirements of various vegetables in each stage of growth [10]. Based on the check results and constructed control plans, corresponding control signals are used by sending them to the microcontroller I/O ports, which allow components such as heaters, fans, and water valves to be operated. In addition, this section maintains live records of system control status on the screen.

4.3.3. Display module

Prepare a driver program of the LCD1602 display to display the data on the right. With the command and data registers of the LCD, you can configure the display mode and the point where the cursor lies. Numbers, such as temperature, humidity, light level and CO 2 are simplified when they are displayed with temperature being displayed to one decimal. You may leave short notes and separators to make it more presentable and readable the screen such as inserting the name of each number before its value and use spaces or special characters to distinguish them.

4.3.4. Key processing module

The system looks for key states with a scanning method. It checks voltage shifts at key ports from time to time to find pressed keys. When a key is seen as pressed, the system writes down the time and keeps looking for release. From key press time and combo patterns, the system gets user meaning: long holds (more than 2 seconds) begin long-press mode for setting values, but quick taps start short-press mode for moving pages or saying yes. In setup mode, working with key combos lets you change (up/down) and agree on set points for temperature, humidity, light, and CO_2 levels.

5. System simulation debugging

5.1. Simulation platform building

In Proteus software, this paper carefully built a system simulation model from the hardware design specs of the smart greenhouse control system. The first step was putting in the AT89C52 microcontroller and setting up its pin functions to match the real circuit needs. Next, different sensors like a DHT11 temperature/humidity sensor, light sensor (using a photoresistor and RV3 potentiometer), and CO_2 sensor (with RV1 potentiometer) were added one by one, making sure the pin-to-pin links were right for data transfer. For actuator circuits, we set up heating wire control with transistor Q2 and relay RL1, linked fan operation through L298N motor driver chip U3 via relay RL1, and set water valve control with transistor Q3 and relay RL2 — all following the actual hardware circuit rules in Proteus. The system also included an LCD1602 display for showing data and a matrix keyboard for user input, finally making a full and correct simulation circuit model.

Copy the program into AT89C52, click run, the system starts up. This interface is the main interface. The four measured data from the first row and the first column are the current temperature, humidity, light intensity and CO_2 concentration respectively. There are four adjustment keys in this system.

Click the Settings button to enter the Settings mode. The current interface displays the upper limit of the system's monitored optimal temperature range. Clicking the "+" button increases this upper limit, while clicking the "-" button decreases it. Re-clicking the "Set" button allows you to adjust the lower limit of the monitored temperature range.

Similarly, by clicking the "+" and "-" buttons, you can adjust the system's lower limit for optimal humidity monitoring. Re-clicking the Settings button will then enable adjustments for the optimal light intensity thresholds, and CO_2 concentration specifications.

After the system detects the lower limit of the appropriate CO_2 concentration range, clicking the "Set" button again will return to the upper limit interface for temperature monitoring. When returning from any upper/lower limit interface, simply press the "Return" button to exit directly. If the current measured data exceeds the preset acceptable range, the system will immediately take corrective actions and trigger an alarm light.

5.2. Simulation result

If the current temperature exceeds the set upper limit, the system will automatically start the fan for heat dissipation, if the measured temperature is lower than the set lower limit, the system will automatically start the heating wire for heating.

If the current humidity exceeds the set upper limit, the system will automatically start the buzzer for alarm. If the measured humidity is lower than the set lower limit, the system will automatically start the water gate for humidification.

If the current light intensity and CO_2 concentration exceed the set upper limit, the system will automatically start the buzzer to alarm. If the measured light intensity and CO_2 concentration are lower than the set lower limit, the system will automatically start the buzzer to alarm.

6. Conclusion

This vegetable greenhouse intelligent control system has completed the full process development from scheme design to software and hardware implementation based on Proteus. Through simulation debugging and actual joint debugging, the feasibility and effectiveness of the system's monitoring of greenhouse environmental parameters and equipment automation control have been verified. The system realizes real-time monitoring and intelligent regulation of temperature, humidity, light, and CO_2 concentration, which can effectively create a suitable environment for vegetable growth. It is much more effective and precise in greenhouse planting than the traditional mode of the management using a manual.

Nonetheless, it is possible to make the project even better. At the hardware level, additional sensors with low-power and high-accuracy can be introduced in order to stabilize the system with time. Control methods at the level of software can be improved to enable the system to address complexes of environmental changes better. To add more features to it, it can provide IoT components which will allow remote real-time monitoring and cloud storage analysis of the information to help drive the digital transformation in farming.

This system will do more in contemporary farming as the need of smart farming increases in future with continuous updates. It can present valuable technological concepts to develop smart farming and contribute to shifting farming towards its automation, extravagance, and carefulness.

References

[1] Chen W H, Mattson N S, You F. Intelligent control and energy optimization in controlled environment agriculture via nonlinear model predictive control of semi-closed greenhouse. Applied Energy, 2022, 320: 119334.

[2] Chen Q, Hu X. Design of intelligent control system for agricultural greenhouses based on adaptive improved genetic algorithm for multi-energy supply system. Energy Reports, 2022, 8: 12126 – 12138.

[3] Zhu M, Shang J. Remote monitoring and management system of intelligent agriculture under the internet of things and deep learning. Wireless Communications and Mobile Computing, 2022, 2022 (1): 1206677.

[4] Maher A, Kamel E, Enrico F, et al. An intelligent system for the climate control and energy savings in agricultural greenhouses. Energy Efficiency, 2016, 9: 1241 – 1255.

[5] Soheli S J, Jahan N, Hossain M B, et al. Smart Greenhouse Monitoring System Using Internet of Things and Artificial Intelligence. Wireless Personal Communications, 2022, 124: 3603 – 3634.

[6] Al-Aubidy K M, Ali M, Derbas A M, et al. Real-time monitoring and intelligent control for greenhouses based on wireless sensor network. 2014 IEEE 11th International Multi-Conference on Systems, Signals & Devices (SSD14). Barcelona, Spain: IEEE, 2014.

[7] Du Y, Xue Z, Zhu Q, et al. Design and application of intelligent control system for greenhouse environment based on CAN bus. 2013 5th International Conference on Modelling, Identification and Control (ICMIC). Cairo: IEEE, 2013.

[8] Subahi A F, Bouazza K E. An Intelligent IoT-Based System Design for Controlling and Monitoring Greenhouse Temperature. IEEE Access, 2020, 8: 125488 – 125500.

[9] Gong W, Zhang X, Wang Y, et al. Review of Intelligent Control Methods for Greenhouse Cluster Systems. 2019 International Conference on Internet of Things (iThings). Atlanta, GA, USA: IEEE, 2019.

[10] Fei X, Xiao-Long W, Yong X. Development of Energy Saving and Rapid Temperature Control Technology for Intelligent Greenhouses. IEEE Access, 2021, 9: 29677 – 29685.