AUTOMATED GREENHOUSE MONITORING SYSTEM

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Introduction

The Smart Greenhouse System is a cutting-edge project aimed at transforming greenhouse management by automating the monitoring and control of key environmental parameters such as temperature, humidity, light, and soil moisture. By maintaining consistent and optimal growing conditions, the system significantly enhances plant health, increases yield, and improves resource efficiency. Through precise control of environmental factors, plants experience reduced stress and uniform growth, leading to healthier and more vigorous development. This system maximizes photosynthesis and ensures efficient water use, which translates into higher growth rates and increased yields. Automation also reduces labor costs and minimizes human error, while efficient energy use and precise water management contribute to significant cost savings and environmental benefits.

Continuous real-time monitoring allows for early detection of potential issues such as exceeding the optimal range of any environmental factor, enabling prompt corrective actions and preventing significant damage or crop loss. The system collects and analyzes data on environmental conditions, plant growth, and system performance, providing valuable insights that facilitate informed decision-making and optimization of growing conditions. Scalable and adaptable, the Smart Greenhouse System supports precision agriculture practices, allowing for the cultivation of diverse plant varieties within the same greenhouse. By reducing the need for chemical fertilizers and pesticides, the system promotes sustainable farming practices and lowers the carbon footprint of greenhouse operations. Ultimately, this project demonstrates the profound impact of automation technology on modern agriculture, enhancing plant production and ensuring sustainable growth.

System Architecture

The system architecture is divided into five main modules:

1. **Sensors Module:**
    - **LDR:** Measures light intensity.
    - **DHT11:** Monitors temperature and humidity.
    - **Soil Moisture Sensor:** Detects soil moisture levels.
2. **Microcontrollers Unit:**
    - **MCU1 (Control MCU):** Reads data from all sensors and controls the system accordingly. It then sends this data to MCU2.
    - **MCU2 (Display MCU):** Receives data from MCU1 and displays it on the LCD. It also sends the data to the Node-RED server for remote monitoring.
3. **Display Unit:**
    - **LCD 20x4:** Displays real-time sensor readings.
    - **Node-RED:** Provides a web-based interface for monitoring and managing the system remotely.
4. **Control Unit:**
    - **Fan and Heater:** Regulate temperature based on DHT11 readings.

- **Pump:** Waters plants according to soil moisture sensor data.
- **Lamp:** Adjusts brightness based on LDR readings.

5. **Alert System:**
   - **Buzzer:** Generates a sound alert when sensor readings go out of the optimal range**.**
   - **LED:** Generates a virtual alert.

Project Architecture

The project is organized into five main layers, each with specific responsibilities:

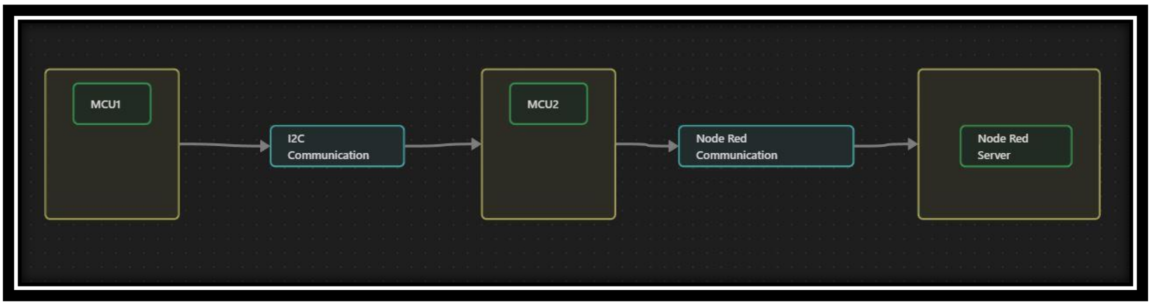
1. **LIB (Library) Layer:**
   - **Error State:** Manages error handling and reporting.
   - **STD Types:** Defines standard data types.
   - **Math:** Provides mathematical functions and utilities.
2. **MCAL (Microcontroller Abstraction Layer):**
   - **DIO (Digital Input/Output):** Manages digital signal input and output.
   - **ADC (Analog-to-Digital Converter):** Converts analog signals from sensors to digital data.
   - **Timers:** Handles timing operations and PWM generation.
   - **EXTI (External Interrupts):** Manages external interrupts for responsive sensor input handling.
   - **GIE (Global Interrupt Enable):** Controls the global interrupt enable/disable state.
   - **UART (Universal Asynchronous Receiver-Transmitter):** Manages pear-to-pear serial communication.
   - **I2C (Inter-Integrated Circuit):** Manages Multi-master-multi-slave serial communication.

3. **HAL (Hardware Abstraction Layer):**
    - **LCD:** Interface for displaying data.
    - **LED:** Provides visual status indicators.
    - **DC Motor:** Controls mechanical components, such as fans and pumps.
    - **Buzzer:** Provides audio alerts.
    - **LDR (Light Dependent Resistor):** Measures light intensity.
    - **DHT11:** Monitors temperature and humidity.
    - **Soil Moisture Sensor:** Detects soil moisture levels.
4. **SERVICES Layer:**
    - **I2C Communication Frame:** Manages I2C protocol communication with a structured frame and check sum for data validation.
    - **Node-Red Communication:** Handles data transfer and communication with the Node-RED server for remote monitoring and control.
5. **APP (Application) Layer:**
    - **AGMS (Automated Greenhouse Monitoring System):** Core application managing the overall greenhouse environment.
    - **Sensors:** Integration and management of various sensors.
    - **Automatic Control:** Implements logic for automated control of actuators.
    - **Display:** Manages data visualization and user interface.

This structured approach ensures modularity, ease of maintenance, and scalability, allowing for efficient development and management of the Automated Greenhouse Monitoring System.

Services Layer

The Services layer provides essential functionalities and communication protocols that support the upper layers of the system. This layer abstracts complex operations and provides a unified interface for managing data exchange and system coordination.



1. **I2C communication frame**

   The I2C Communication Frame is a critical component of the Services Layer in the Automated Greenhouse Monitoring System (AGMS). It is responsible for managing data transmission between the two MCUs using the I2C protocol with a standard frame structure and a check sum byte at the end for data verification.

- **Initialization Functions**

  1. **Communication_enuInitMaster:** Initializes the microcontroller as the I2C communication master.
  2. **Communication_enuInitSlave:** Initializes the microcontroller as the I2C communication slave.

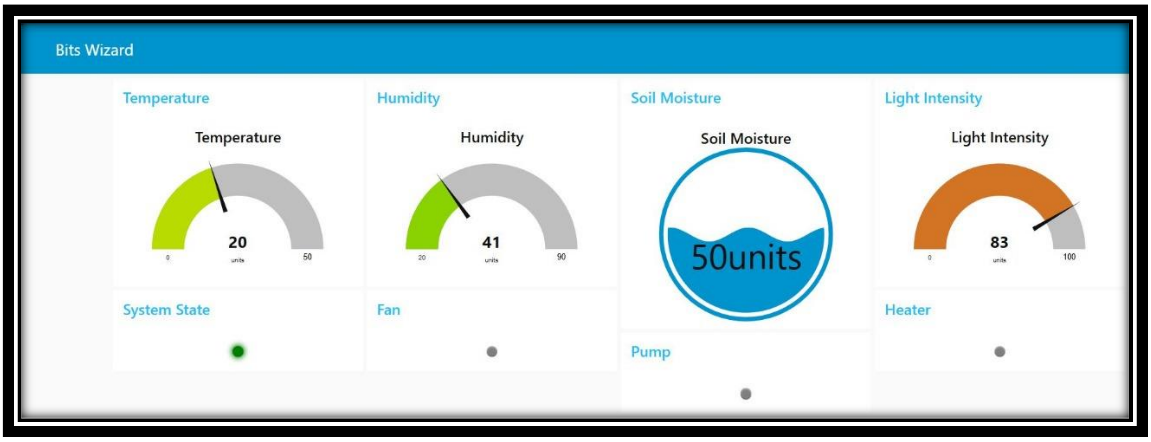
- **Data Transmission Functions**:

  1. **Communication_enuSendFrame:** Starts the I2C communication, sends a frame of data from the master to the slave, calculates the checksum of the data frame, and finally stops the I2C communication to prevent bus starvation.
  2. **Communication_enuReceiveFrame:** Checks if the slave's address matches, receives a frame of data at the slave, compares the calculated checksum with the received checksum to verify data integrity, and return the error status.

The I2C Communication Frame module ensures robust and reliable data exchange between microcontrollers and sensors within the AGMS. It provides functions to initialize the I2C communication in both master and slave modes, send data frames from the master to the slave, and receive data frames at the slave. The module also includes error handling to manage any issues that arise during communication, ensuring the system operates smoothly and efficiently.

2. Node-Red Communication

The Node-RED module handles data transmission from the system to the Node-RED server, enabling remote display through a user-friendly interface.



- **Initialization Function**

    1. **NodeRed_Communication_enuInit:** Sets the direction of the USART Tx and Rx pins, and Initializes the UART for serial communication.

- **Data Transmission Function**:

    2. **NodeRed_Communication_enuSendDatatoServer:** Converts sensor data into a string format then sends the formatted string data to the Node-RED server via USART .

- **Helper Functions**:

    3. **Struct to String Conversion:** Converts the members of a struct to a single formatted string, each sensor reading is separated by a semicolon, and the string ends with a dollar sign as the Node-Red desires the data in this format.

The Node-RED Communication module facilitates the transmission of sensor data from the AGMS to the Node-RED server, allowing for real-time remote monitoring. This module is essential for integrating the AGMS with Node-RED, providing users with a powerful tool for managing greenhouse conditions remotely.

Application (APP) Layer

The APP layer is the topmost layer in the Automated Greenhouse Monitoring System (AGMS) architecture. It is responsible for implementing the core functionalities of the system, integrating various services, and providing an interface for interaction with the system. The APP layer is divided into several key modules, each handling a specific aspect of the greenhouse management.

1. **Automated Greenhouse Monitoring System (AGMS)**

    AGMS module is the central component in the Application (APP) layer of the project. It coordinates the interaction between various sensors, automatic control mechanisms, display units, and communication systems.

    - **Initialization Functions**

        1. **AGMS_enuInit_AutomaticControl:** Initialize the master by Initializing the sensors used for environmental monitoring, sets up the master communication for data transmission between MCUs, and initializes the automatic control system.

2. **AGMS_enuInit_Display:** Sets up the slave communication for data reception from the master MCU, Sets up the slave communication for data reception from the master MCU, and Prepares the display system for showing real-time sensor data.

- **Running Functions**:

3. **AGMS_enuRunning_AutomaticControl:** Reads sensor data and stores it in structure, packs the sensor data into a communication frame for transmission to the second MCU, controls the heating, irrigation, and lighting systems based on the sensor readings, and activates the alert system if any parameter is out of the optimal range .
4. **AGMS_enuRunning_Display:** Receives sensor data from the control MCU (MCU1), displays the updated sensor data on the LCD, and sends the sensor data to the Node-RED server for remote monitoring.

The AGMS module is crucial for the operation of the Automated Greenhouse Monitoring System. It ensures that environmental conditions are continuously monitored and adjusted to maintain optimal conditions for plant growth. The module integrates sensor readings, automatic control mechanisms, and data display, providing a comprehensive solution for efficient greenhouse management. By leveraging the communication capabilities with the Node-RED server, the AGMS module also facilitates remote monitoring and control, enhancing the usability and functionality of the system.

2. **Automatic Control Module (AC)**

The Automatic Control (AC) module is a critical component of the Automated Greenhouse Monitoring System (AGMS), responsible for maintaining optimal environmental conditions within the greenhouse. This module includes the initialization of control systems, and the regulation of temperature, humidity, soil moisture, and light intensity based on sensor readings. Below is a detailed description of the AC module's functions:

- **Initialization Function**

1. **AC_enuInitSystem:** Initializes the HAL layer such as: LED system, DC motors, and buzzer, then sets up timers for PWM control of the lamp, fan, heaters, and pump, and finally initializes external interrupts for the buzzer.

- **Control Functions**:

2. **AC_enuControlHeatSystem:** Controls the heating system based on temperature and humidity readings. Turns on the heater and adjusts its speed using PWM if temperature and humidity are below the minimum thresholds. Controls the fan similarly, turning it on when temperature and humidity are above maximum thresholds and adjusting its speed accordingly .
3. **AC_enuControlIrrigationSystem:** Controls the irrigation system based on soil moisture levels. Turns on the pump and adjusts its speed using PWM if soil moisture is below the minimum threshold and then turn it off if the soil is back wet.
4. **AC_enuControlLightIntensitySystem:** Turns on the lamp and adjusts its intensity using PWM if light intensity is below the minimum threshold.
5. **AC_enuControlAlertSystem:** Monitors the system for any parameter that goes beyond the critical error thresholds. Activates the buzzer and error LED if any parameter is out of the acceptable range.

The Automatic Control module is designed to ensure optimal environmental conditions in the greenhouse by automatically regulating heating, cooling, irrigation, and lighting systems. By continuously monitoring sensor readings and adjusting actuators through PWM signals, the module maintains the desired climate and alerts (As shown in the figure)the system when any parameter exceeds safe limits. The integration of sensors, actuators, and control logic within the AC module makes it a vital component.

3. Display Module (DM)

The Display Module (DM) is responsible for presenting real-time sensor data on an LCD screen. This module provides an intuitive interface for users to monitor the greenhouse's environmental parameters and system state. Below is a detailed description of the DM functions:

- **Initialization Functions**

1. **Display_enuInit**: Initializes the LCD display, preparing it for data output.

- **Display Function**:

    2. **Display_enuReading:** Displays the current sensor readings for temperature, humidity, soil moisture, and light intensity. Also shows the system state (Normal or Error) based on the data provided by the sensor readings.

The Display Module is designed to provide a clear and concise visualization of the greenhouse's environmental conditions and the system's operational status. By continuously updating the LCD with real-time data, users can easily monitor and manage the greenhouse environment.

4. **Sensors Module (SM)**

The Sensors Module (SM) of the Automated Greenhouse Monitoring System (AGMS) is responsible for gathering environmental data from various sensors. This module interfaces with the Light Dependent Resistor (LDR), Soil Moisture Sensor, and DHT11 sensor to obtain readings for light intensity, soil moisture, temperature, and humidity. The collected data is then processed and made available for other modules within the system. Below is a detailed description of the SM functions:

- **Initialization Function**

    1. **Sensors_enuInit:** Initialize the ADC and all the sensors (LDR, DHT, soil moisture).

- **Reading Function**:

    2. **Sensors_enuGetReadings:** Get all sensors' readings and do the right mapping for their values, then fill up the struct passed to it.

The Sensors Module is designed to seamlessly integrate various environmental sensors into the AGMS. By initializing and gathering data from the sensors, the SM provides crucial inputs that enable the system to monitor and control the greenhouse environment effectively. The initialization and reading functions ensure that the sensors are properly set up and their data is accurately captured and processed. .

Conclusion

The Automated Greenhouse Monitoring System (AGMS) represents a significant step forward in the field of precision agriculture, providing a comprehensive solution for maintaining optimal environmental conditions within a greenhouse. By integrating a robust array of sensors, automated control systems, and advanced communication protocols, the AGMS ensures that parameters such as temperature, humidity, soil moisture, and light intensity are continuously monitored and adjusted to meet the needs of the plants.

The project successfully achieved its primary objectives, including the development and implementation of multiple software layers: MCAL, HAL, SERVICES, and APP. Each layer played a critical role in the overall functionality of the system. The MCAL layer handled low-level hardware interactions, the HAL layer provided a higher abstraction for sensor and actuator control, the SERVICES layer facilitated communication and data processing, and the APP layer integrated all components to enable seamless operation and user interaction.

Through rigorous testing and validation, the AGMS demonstrated its capability to autonomously manage the greenhouse environment. The system's ability to detect deviations from optimal conditions and automatically trigger corrective actions, such as activating heaters, fans, irrigation systems, and grow lights, ensures that plants are consistently provided with the ideal growing conditions. Additionally, the integration with Node-RED allows for remote monitoring and control, enhancing the user experience and offering real-time insights into the greenhouse status.

In conclusion, the AGMS not only simplifies greenhouse management but also optimizes resource utilization, reduces labor costs, and promotes sustainable agricultural practices. This project lays the groundwork for further advancements in automated agricultural systems and underscores the potential of technology to revolutionize traditional farming methods. Future enhancements could include the integration of advanced machine learning algorithms for predictive analytics and the expansion of the system to support a wider range of environmental sensors and control mechanisms. The success of this project highlights the importance of interdisciplinary collaboration and the transformative power of innovation in addressing global food security challenges.