Design and Realization of a Smart Irrigation System on Sloping Lands and Hills

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Abstract

This paper presents an approach for design and realization of smart irrigation systems on sloping lands and hills. In the proposed system, the data from temperature sensors, humidity sensors, and rain-detection sensors are first acquired, then calculated by using STM32 microcontroller, and transferred to a data center via wireless communication. In addition, a computer-based interface is developed to acquire and monitor the data about trees on the hills. Four smart irrigation modes have been developed for the system in order to perform irrigation for different cases including manual, timing, schedule, and fully automatic modes . The preliminary results show the desired performances of the proposed system when operating with different irrigation modes.

Keywords: Smart irrigation, Localized Irrigation, MCU, Soil moisture sensor, Rain detection sensor

1. Introduction

Vietnam has a complex terrain in which 3/4 of the territory areas are mountains and hills. Mountainous and sloping lands distributed in many parts of the country raise challenges for cultivation. Water on steep hillside slopes can be stored through conduits or by suspended lakes. However, the capacity of the stored water is generally small, it therefore is necessary to develope a smart and effective irrigation system to help farmers efficiently utilize water resources as well as to reduce human labours. One of the tasks of an automation measurement system is to study and apply smart irrigation systems into automated systems. Generally, irrigation modes include: Localized Irrigation System/Low Volume Irrigation System, Drip Irrigation/Strickle Irrigation, and Sprinkler Irrigation.

During the global agriculture revolution, automated systems for irrigation have been widely used and gained many benefits in developed countries, i.e., US, France, Israel, to name just a few. Recently, the automated irrigation systems have been studied and applied in Vietnam. In fact, when applying the systems to Vietnam, one needs to do researches on soil, crop, irrigation to adapt with the local region natural conditions.

Smart water-saving irrigation systems have been studied in previous works. For example, in [1], the authors used fuzzy logic algorithms and developed wireless sensors for measuring soil moisture as well as air-to-air irrigation. A study on soil temperature and humidity monitoring system using WSN was performed in [2] in which the authors used the measurement of the parameters in four soil layers with depths of 10, 20, 30 and 40cm to fit many different crops. More recently, applying the Internet of Things (IoT) for sensor systems and actuators for smart irrigation is also a new research trend [3], which increases the flexibility of the design system. A new monitoring system using heat images in the study of [4], has been proposed for intelligent irrigation. In the context of Vietnam, especially in the north-western provinces, with mountainous and hilly terrain, the development and realization of a smart irrigation system for plants on the sloping hillside is of high demand [5].

From the above analysis, it can be seen that it is necessary to do research and develop smart irrigation systems for sloping hillside crops suitable to Vietnam conditions. The setting-up demands for this system are:

- Many irrigation modes to save electricity and water resources
- Simple, easy to operate, capable of flexible integration in automation systems
- Open, easy to expand, can be controlled remotely via PCs or smart phones
- Low cost
- High stability, robustness.

2. System design

2.1. System block diagram

The design system is described in Fig. 1, in which the local device acts as the Slave. A center

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device that collects data from slave stations, transfers control decisions from users to local stations.

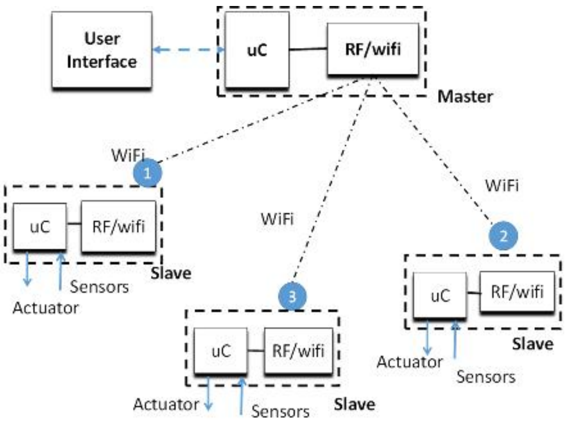

Fig. 1. Schematic block of the irrigation system.

2.2. Hardware design

2.2.1. Local device

The local device is responsible of monitoring and executing control commands. The server receives data from the nodes, updates the device status to the human-machine interface, and decides the control commands according to each of the installed modes. A description of the Local device is shown in Fig. 2.

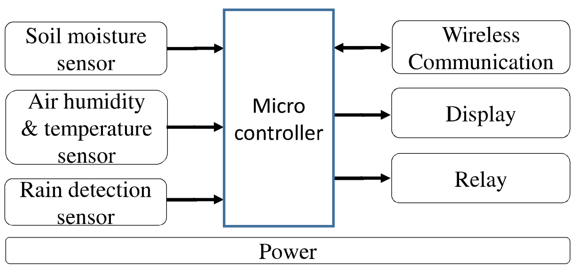

Fig. 2. Block diagram of the local device.

The local device is based on the ST Microelectronic STM32F103 microcontroller (MCU). This is a 32-bit high performance ARM Cortex-M3 MCU, with low power consumption, up to 72Mhz operating frequency, 256Kb Flash memory, 64Kb SRAM. It supports multiple peripherals such as two 12-bit ADCs, two 12-bit DACs, and eight sets of 16-bit timers. It also supports multiple interface interfaces like two I2C, fives UART, three SPI, and one USB & CAN.

This central microcontroller is responsible for reading the measured values from the sensor, displaying and transmitting data to the Master via the communication block. At the same time, the microcontroller is also responsible for receiving the control signal from the master and performing the ON/OFF control of the pumps through relay switching.

Sensors

Sensors used in the Local device include: temperature and humidity of the air in the monitoring area, humidity around the irrigated area and rainfall connected to the microcontroller. Based on weather conditions, Local device will decide the appropriate irrigation mode.

To monitor the environmental temperature and humidity parameters, the DHT11 sensor is used. Some of the key parameters of the DHT11 sensor are listed as follows:

- Humidity range: 20%-90%
- Temperature range: 0-50ºC
- Humidity error: ±5% RH
- Temperature error: ±2ºC

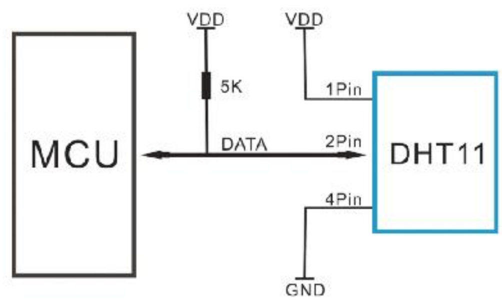

Fig. 3. Connection between DHT11 sensor and MCU.

To determine the humidity of the soil we use CBI010106 sensor operated according to the principle of induction with parameters as follows:

- Measure range: 0 - 100%
- Supply voltage: Vcc= 3.3V – 5.0V
- Output:
  + Analog: 0V - Vcc
  + Digital High (Vcc) or Low (0V) (when setting alarm threshold)

The detection of rain through CBI02001 sensor is operated according to the principle of induction, the basic parameters are as follows:

- Detecting status: rain or no rain and the rainfall
- Supply voltage: Vcc = 5.0V
- Output:
  + Analog: 0V – 5V
  + Digital High (Vcc) or Low (0V)

Fig. 4. Soil moisture sensor (left) and rain detection sensor (right).

Communication module

The communication unit performs data exchange between the server and the client. In this study, we use Wifi for communication due to its low cost and advantages. To connect the measuring device to the server remotely, we used the Wifi module ESP8266-01. Here are some parameter specifications of this module:

- Supports 802.11 b / g / n standard.
- Serial communication interface UART with the baud rate up to 115200.

Three operation modes: Client, Access Point,

Both Client and Access Point.

- Supports both TCP and UDP communications.

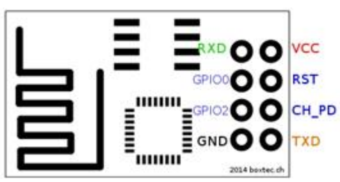

Fig. 5. Connection schematic of the Wifi module.

Under normal conditions, if we add more antennas and increase the power of a Wifi transmitter, the Wifi can transmit up to 400m which is a suitable distance for the applications.

Display module

The display module has the function of providing information, displaying the soil moisture at the measuring point. The relay block is responsible for switching power supplies (i.e., valves and water pumps).

LCD HD44780 is a type of display commonly used in microcontroller applications. It has the ability to display a variety of characters, visual (letters, numbers and graphic characters) and allow up to 16 characters per line. After measuring the environmental parameters, it will display information on the LCD screen.

2.2.2. Center device

The center unit is also based on ST Microelectronic STM32F103 microcontroller (MCU). The description of the center device is shown in the following figure:

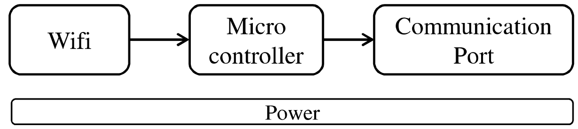

Fig. 6. Block diagram of the Center device.

The main function of the center device is to coordinate the operation of the system, which mediates communication between the human interface and the local device.

2.3. *Software design*

2.3.1. Microcontroller software

The software program is developed on STM32 and written in C#. The algorithms of this program are shown in the following figure:

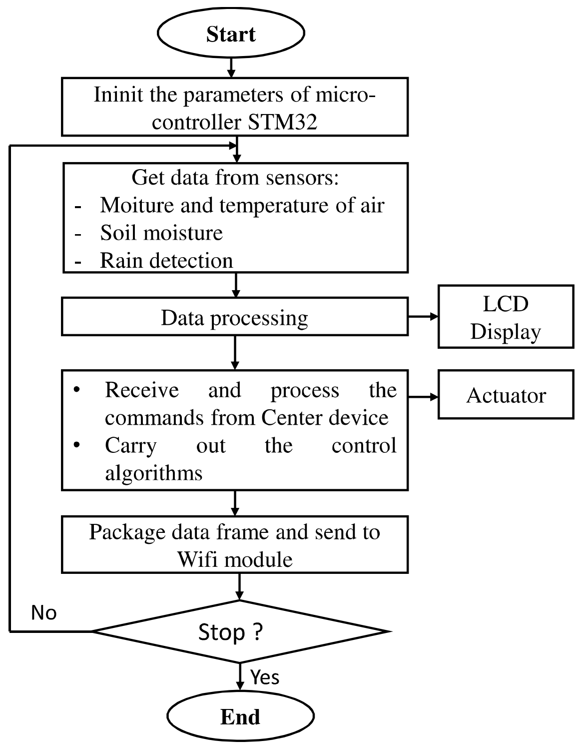

Fig. 7. The algorithm of the local device.

The main program execution algorithm is implemented as Fig. 8. Accordingly, after initializing the ADC, UART, and peripheral components in the microcontroller and configuring the Wifi module, we proceed to read the measured values such as temperature and humidity from the soil and conductive sensors. These values are stored in the SE string with the following structure:

DB*sh*ah*t*ps*rs*CS

where:

DB: frame start delimiter

sh: soil moisture value

ah: air humidity value

t: temperature value

ps: pump state

rs: rain condition

CS: frame end delimiter

Pump parameters and rainfall status are updated according to the current status of the equipment and the environment. Then, the SE string is sent to the server. Next, the client receives a structured RE string:

DB*cps*CS

where **cps** is the pump status.

By separating this string, the microcontroller determines the pump control. Finally, the microcontroller updates the value in the SE string and proceeds to send it to the Server if requested to continue.

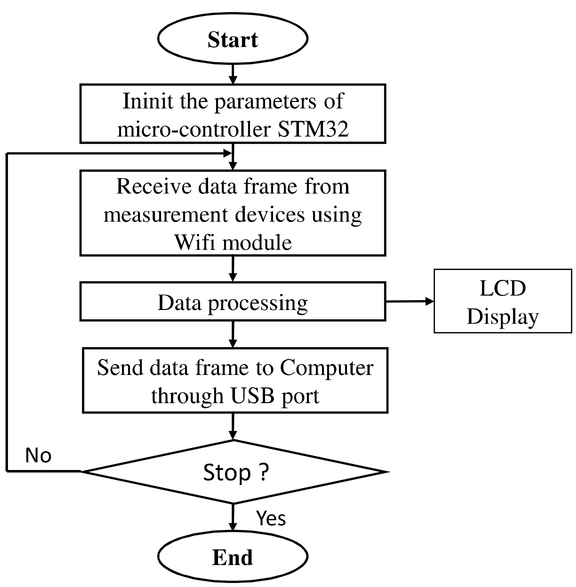

Fig. 8. The algorithm of the Center device.

2.3.2. Computer Software

Control and monitoring software provides users two basic interfaces for communicating with the system:

Monitor Interface: Enables users to view parameters of the environment, system states through the Analog Meters and Indicators on the screen. In addition, this interface allows users to monitor the evolution of environmental factors by using data stored in the database to build graphs over time and display on the screen.

Controller Interface: Allows the user to directly control or install control parameters for the irrigation process. The interface is built towards simplicity and user-friendliness, even worked for users are with less computer skills and experience. Algorithm to execute program on Server is provided in the following figure.

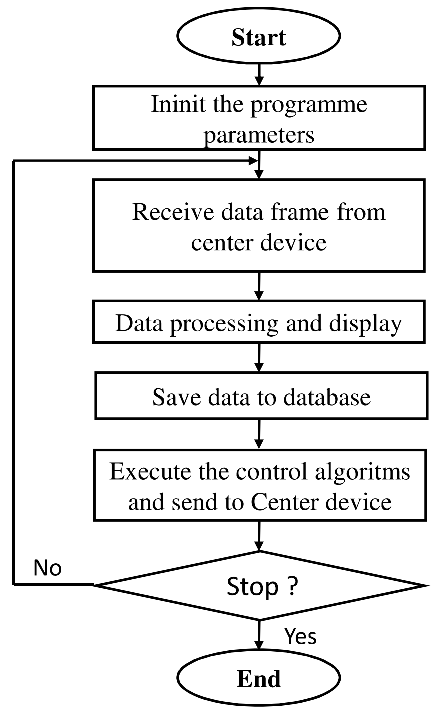

Fig. 9. The algorithm of the software program on personal computer.

a. Irrigation modes

The system allows users to perform the irrigation in the following modes:

- *Mode 1:* Manual mode. This mode allows the users to directly control the watering process by performing the operation on the monitor screen.
- *Mode 2:* Timing mode. The mode allows the users to set the watering interval of the day. This mode is especially suitable for new crops. With this mode, users can rely on their experience to make decisions about time to irrigate the plants, then make appropriate adjustments to find the optimal conditions for crops.
- *Mode 3:* Schedule mode. This mode allows the users to set the watering days of the week and the duration for irrigation during a day. This mode allows operation from week to week for a long time.

- *Mode 4*: Fully automatic mode. With this mode, the users only need to set the necessary moisture threshold parameters, and time to process the irrigation. The automatic picking of effective irrigation time refers to the time when the electricity price is in the off peak time, or the time with raining.

2.4. *Communication*

The components of the system are connected through a LAN (Wifi network). In addition to advantages like the low cost, and high data transfer rates, the TCP/IP protocol used in the network also allows for quick and easy solution to the problem of system expansion.

3. Results

In preliminary research, we integrated central circuits and local circuits on a main circuit board and tested the smart irrigation features of the device. The hardware circuit board is shown in Fig. 10.

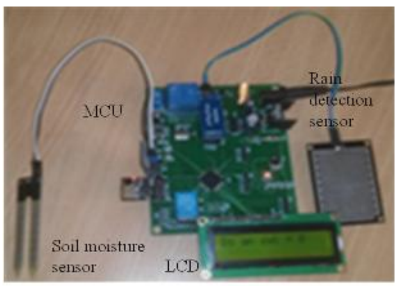

Fig. 10. Hardware configuration.

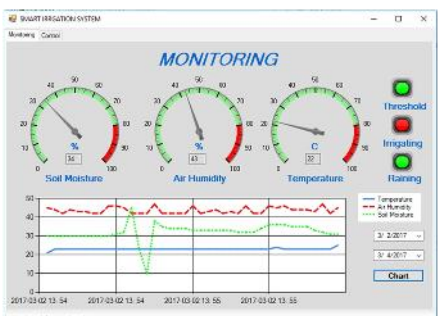

Fig. 11. Interface monitoring irrigation system.

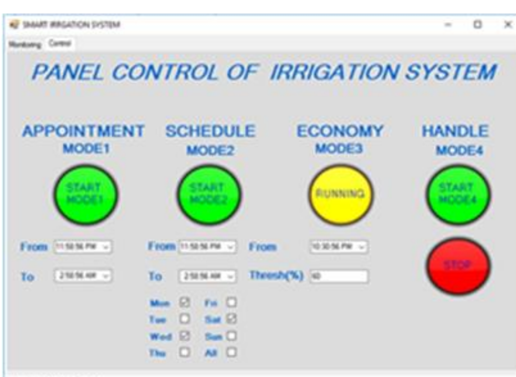

Fig. 12. Interface for Irrigation System.

The monitoring and control interface on the computer is shown in Fig. 11. This interface allows the display of parameters for temperature, humidity, and humidity of the soil in numerical and graphical form. The interface window in Fig. 12 shows various modes of irrigation, such as Appointment mode, Schedule mode, Economy mode, and Handle mode.

4. Conclusion

We have presented an approach for design and implementation of smart irrigation system for plants on sloping lands and hills. The system is operated according to the setting-up demands. By the experiments, the hardware works well and stable. In addition, the measured data by our system were validated by comparing with results by other commercial sensors. Besides, the computer communication module using Wifi provided stable data. In future works, we plan to test the system in the real scenario to adjust the parameters and improve the performance of the system.

Acknowledgement

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