AUTOMATION OF GREENHOUSES WITH IN-HOUSE AND REMOTE MONITORING/CONTROL SYSTEM

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Abstract. This paper provides the design and implementation of a microcontroller-computer incorporated monitoring and control system for local greenhouses in Oman to achieve maximum plant production. The levels of temperature, percentage of relative humidity, and soil moisture are collected by the microcontroller constantly from the sensors, and displayed them instantly on a local LCD and at the remote computer regularly. The in-house microcontroller generates accordingly signals to control the climate through the conditioning equipments; fans, heaters, and water pumps. The user can monitor the current and previous status of the greenhouse remotely in a computer through a developed graphical user interface (GUI) database.

Keyword. Automation; Greenhouse; Microcontroller; Sensors.

INTRODUCTION

A. Literature survey

Nowadays there have been enormous advances achieved in the electrical hardware/software technologies. Advancement in technologies makes people's lives easier through providing solutions to various problems. In the agricultural sector for example, measures have been taken to utilize these advancements to increase the quantity and quality of agricultural production [1]. In the past, farming was done manually by employing large number of laborers. Traditional agricultural production depends on weather changes making it seasonal, and consequently a minor change in a weather condition greatly affects the quantity and quality of the plants [2]. Greenhouses provide a controlled environment for growing fruits and vegetables plants.

Modern greenhouses are equipped with in-house automated climate control systems which monitor temperature changes and control accurately the indoor environment through heaters and/or cooling systems, and air ventilation. This reduces the vulnerability of crops to diseases, and as a result enhances the plant production. There are other benefits of automating the climate control and plants irrigation through reducing the labor requirements, cost efficient, saving energy, and environment friendly. References [3] through [8] demonstrate different techniques proposed by the researchers to automate the work in greenhouses. Most of these techniques use the microcontroller as a core processing and controlling unit, because it is an affordable programmable solution that can be used for simultaneous monitoring and controlling tasks in such low density and speed processes. This is because the microcontroller is an inexpensive single-chip computer with low power drives facilities [9], [10]. Sensors and actuators are used in these proposed systems as peripherals to the microcontroller to achieve the monitoring/control tasks. For remote monitoring purposes, researchers integrate the microcontroller with one of the Zigbee, Blutooth, or GSM communication modules.

B. Greenhouse Cultivation in Oman

The growing of crops in dry regions is a great challenge for the agricultural sector. Countries with dry regions, like Oman, suffer from food shortages due to unfavorable conditions, and therefore productive agriculture becomes an issue. In such cases, the need to establish a controlled environment where these factors could be monitored and maintained is a vital concern and could be achieved by plant growing in a greenhouse. In Oman, many people have started growing crops like cucumber and tomatoes in classical greenhouses due to their short cycling period and high yielding capacity.

The concept of greenhouse farming is picking up fast in Dhofar region. Its growth statistics could be judged from the fact that five years back there were no greenhouses in Dhofar, but today there are not less than 24 to 30 big greenhouses in and around Salalah. Previously, the farmers were depending on shaded farms because they were not aware of greenhouse farming. Today the scene is entirely different, almost all those who were using shaded farming have converted into greenhouse farms, and the farmers enjoyed because of the achieved increment in their productivity.

The local farmers still using manual operation in their greenhouses by depending on the labors in the cooling/heating process and plants irrigation, resulting in high cost and less productivity due to bad control of the plants growing conditions. This is because the local greenhouses have no humidity and soil moisture sensors, which in turn increases the plants diseases due to the lack of good ventilation and increase of humidity.

C. *Overview of the developed system*

The developed monitoring and control system provided in this paper for greenhouses uses the hardware/software facilities available in the PIC16f887 microcontroller. For climate/irrigation control, the temperature, humidity, and soil moisture sensors are interfaced to the microcontroller to gather constantly the air and soil moisture conditions inside the greenhouse. To maintain the optimum plant growing environment, the microcontroller is programmed to process the gathered data, and compare them with preset optimum values. In case of deviating out of the optimum climate/soil moisture values, the microcontroller is designed to generate automatically control signals to the interfaced fans for environment alleviation, and/or to the water pump for plants irrigation.

For monitoring purpose, the developed system is designed to provide the user with real-time continuous readings of temperature, humidity, and soil moisture locally inside the greenhouse through the attached liquid crystal display (LCD) to the microcontroller. At the same time, the microcontroller keeps sending the collected readings, via the serial communication port, to a remotely located computer. The computer stores the received readings, regularly, in a database developed especially to provide the user with current and past climate/irrigation information inside the greenhouse. The use of computer offers monitoring facility can be extended for multi-greenhouses at the same time.

METHODOLOGY

A. System Design and Hardware Description

The following objectives are taken into consideration in designing the greenhouse climate monitoring and control system:

1. Improve the greenhouse crop production in Oman by building a system prototype that is cost efficient, easy to maintain, and appropriate to the moderate/hot weather environment of different areas in Oman.
2. Design a user-friendly and hassle free system that does not require professional experience to install and operate.
3. Utilizes the features of a microcontroller to automate the work in greenhouse by monitor and control climatic conditions.
4. Record and monitor the greenhouse present and past conditions through a remote computer.

Figure 1 below shows the system's block diagram. As shown in the figure that the microcontroller acts as the core of operations. It receives and sends data to other peripherals in the system. The data received from three sensors (temperature, humidity, and soil moisture) through the microcontroller input ports, and sends them to the LCD to be displayed sequentially. The microcontroller is also sending the sensors reading to a computer in periodical intervals to be saved in its database. The microcontroller generates signals to turn ON and OFF the conditioning equipments; fans, and water pump, to control the greenhouse environments and plants irrigation. The keypad and LCD provide a human interface device to set the system parameters, and for local and instant monitoring of the greenhouse conditions.

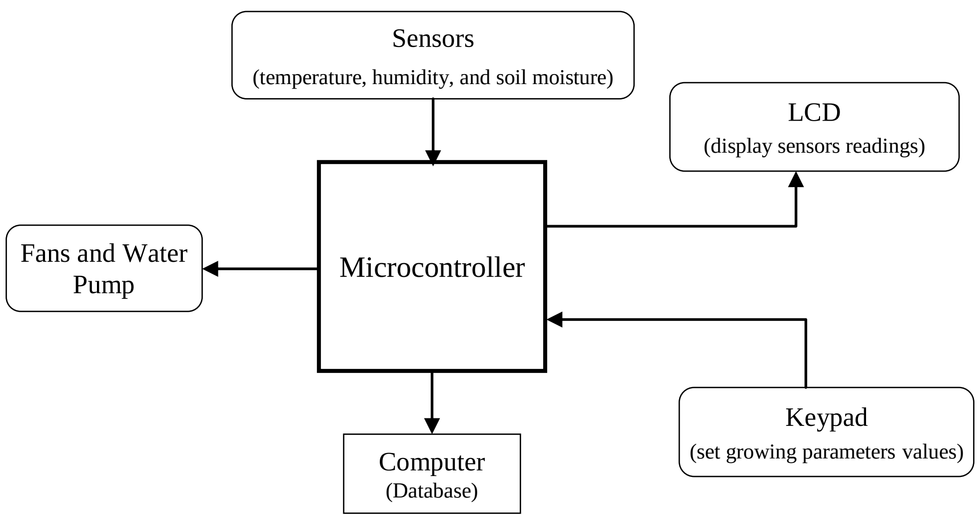

Figure 1: System Block Diagram

The system prototype built by using PIC16F887 microcontroller produced by Microchip company. It has 40 pin of which 35 of them can be used as I/O ports with individual direction control. From 35 I/O port lines, there is 14 lines has built-in analog to digital converters (ADC) where three of them used to receive analog signals from the sensors. The temperature sensor used in the system is the TMP35 temperature sensor manufactured by Analog Devices company. It is a precision centigrade temperature sensor, and its output is linearly proportional to the centigrade scale with a wide range extends from about -30 ^{o}C to 125 ^{o}C. The humidity sensor used in the system is from Honeywell company, HIH-4030. It is a 3-Pin surface mount device (SMD) that measures the relative humidity and outputs respective voltage readings. It is easy to interface with the PIC microcontroller as it is only needed to be connected to any ADC port. The soil moisture is measured by utilizing probes that are buried a few centimeters away from each other. The voltage measured between these probes are detected and sent to the ADC of the microcontroller for processing. The system uses a C-51847 (20x4) LCD. It has 16 pins, and 12 of them are connected to the microcontroller.

B. Software Description

The PIC16f887 is a programmable microcontroller. MikroBasic was used to write and compile the program used for the PIC16f887. MikroBasic compiles the Program and provides a hexfile which is then downloaded into the PIC16f887 microcontroller. The program is composed of various subroutines. The developed program is depicted by the flowchart in Fig. 2.

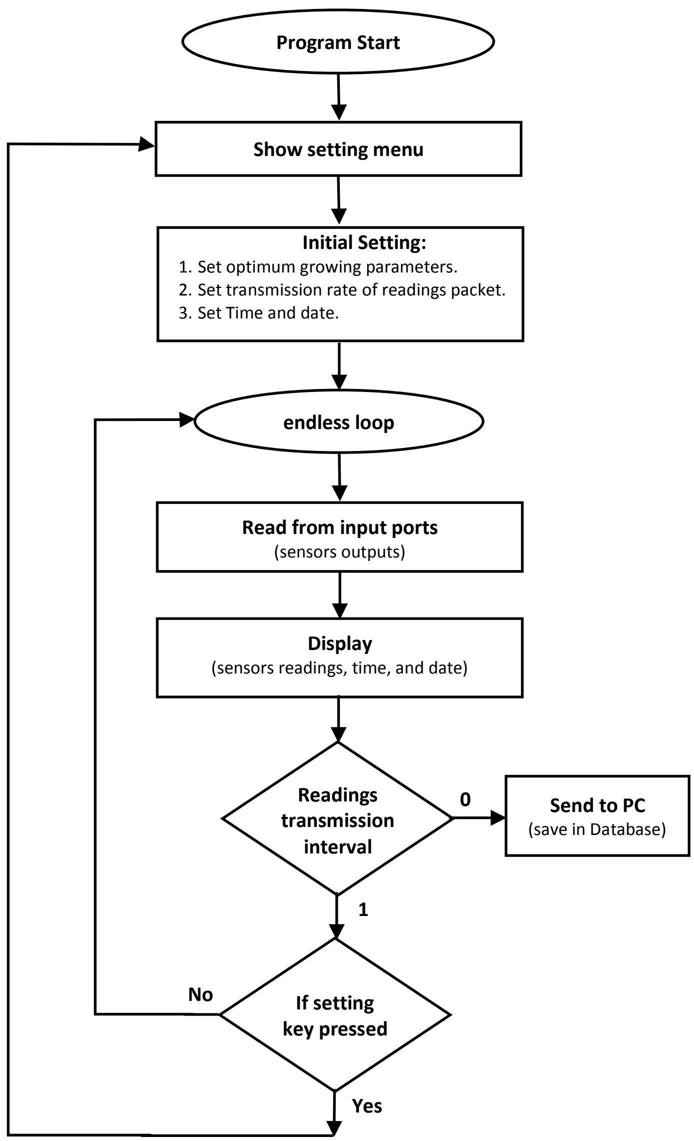

Figure 2: System Flowchart

It can be shown from the flowchart that the program starts with initialization of the three growing parameters; temperature degree, humidity level, and soil moisture intensity. In this stage, the transmission rate of the packets of sensors readings (packet/hour) to the computer is chosen, and also setting the date and time. The system will then enter to endless loop receiving continuously signals from the three sensors, compare them with the preset values and give orders, if needed, to the conditioning equipments to switch them ON/OFF. At the same time, the microcontroller (as shown in the flowchart) converts the sensors' electrical signals into decimal values and displays them instantly by the local LCD. At the end of each predefined periodic interval, the microcontroller sends the collected readings (e.g. every one hour) as a packet of data to the computer to be saved in its database. The keypad is checked constantly in each loop to detect press of any key, if any, where in this case the program will exit the loop to revise the systems' parameters.

The graphical user interface (GUI) of the database in this system, as shown in figure 3, was designed using Visual Studio. Microsoft Visual Studio is an integrated development environment (IDE) from Microsoft is used to develop a GUI applications along with Windows Forms. Visual Studio supports different programming languages by means of language services, which allow the code editor to support nearly any programming language. Built-in languages include C/C++ (via Visual C++), VB.NET (via Visual Basic .NET), C# (via Visual C#), and F# (as of Visual Studio 2010) [11].

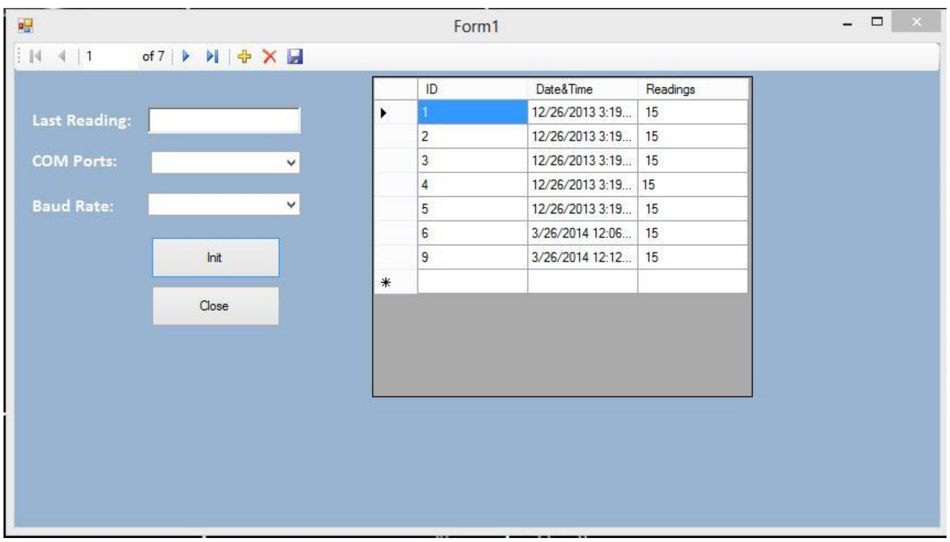

Figure 3: GUI of Database

DISCUSSION

To help in designing and prototyping the system, two supplementary tools were used. The simulation of the designed system was done by PROTEUS 7.10 software, PROTEUS 7.10 can be used for microprocessor simulation, schematic capture, and printed circuit board (PCB) design. On the other hand, A MATRIX programmer/development boards from MATRIX company, UK, were used in developing the prototype of the system for programming the PIC16F887 microcontroller and testing the system functionality. MATRIX boards are suitable for programming various kinds of PIC microcontrollers of different pin sizes.

As a future work, the monitoring/control system can be developed more by addition of soil pH analysis and automatic compost injector through the irrigation system. This unit will be responsible in analyzing the nutrient content of the soil and also inject compost into the soil in regular intervals. Also, the level of light in the greenhouse can be controlled especially in a rainy or cloudy days (e.g. summer season in

Salalah) when there is very less sunlight. The light sensor should be added and the system then will enhance the photosynthesis process by switching ON the internal lighting bulbs. Another development can be done through adopting the renewable energy system via solar panels for energy generation. This will supply the greenhouse with the needed amount of energy for its functioning to reduce the total costs and for electricity shut down cases. Finally, addition of GSM modem will enable the user to monitor the greenhouse condition anywhere and anytime when roaming by an SMS messages on the user's mobile phone.

CONCLUSION

Having a greenhouse monitoring and controlling system allows the farmers to grow crops which are not on season as the system is capable of providing the necessary climatic conditions. The automation of greenhouse activities provides optimum plants growing conditions, and as a result increases its productivity. The automation of greenhouse is also reduces the labor manpower greatly, and avoids wasting of energy due to unnecessary lighting and/or heating/cooling which they represent the main operation costs. It is shown that the greenhouse automation can be done in affordable cost by using a set of sensors, microcontroller, and different climate conditioning equipments. Also, the computer can be added, as an optional choice, to the system to provide remote monitoring and control facility, and the historical profile of the greenhouse status will be available at any time. Besides that, the use of computer helps in integrating the monitoring and control activities in big multi- greenhouses agricultural projects. Finally, by connecting the computer to the internet, the monitoring and control of greenhouse(s) can be done anywhere and anytime.

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