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Solar Powered Microcontroller-based Automated Irrigation System with Moisture Sensors

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Abstract-
In traditional irrigation approach where water is irrigated on the land without adequate control measures, crops sometimes undergo increased stress with disparities in the soil moisture which consequently reduce the crop performance and output. In this paper, we come up with a prototype to increase crop yield while considering adequate agricultural water management and labour reduction, by adequate control measures in the irrigation process. An automatic irrigation system is designed and developed by integrating several hardware and software features. The system is designed to determine when exactly the soil of crops need water and deliver a controlled amount of water to the root zone of the crops based on the soil moisture state. With the microcontroller, the data obtained from the soil at the roots of the crops will determined how much water for irrigation is needed at a point in time, and supplies it, thereby incorporating good water management practice. The system is designed to run 24/7 on renewable solar energy.

Keywords: Agriculture, Irrigation, Mechactronic, Microcontroller, Solar

1.   Introduction

Irrigation is the process of artificially supplying water to land or soil. It is used to aid in the growth and development of agricultural crops, revegetation of damaged soils in dry areas, maintenance of landscapes, and during periods of insufficient rainfall [1]. Water is a resource that is needed by all living things. It is very valuable and needs to be used with moderation so as to preserve it for as long as possible. Agriculture as an industry has very high-water consumption. More often than not, water is not used efficiently and significant volumes of water are misused. Very soon, these wastes will lead to water costing large sums of money [2].

It is safe to call water the most important liquid on the surface of the earth. Water is probably the most excessively used resource on earth. Mass irrigation is a commonly used technique in the watering of crops in agriculture. This technique signifies immense wastage since the quantity of water given is in surplus of the crop's requirements. Irrigation of crops is a significantly time-expending activity; to be done in a feasible amount of time, it also demands a huge amount of human resources. Conventionally, all labour required in the irrigation process were carried out by humans [3]. With the influence of Mechatronics in agriculture, our ecology is gradually returning to its "green" state while also dropping cost and increasing efficiency by diffusing it with technology that is not destructive but advantageous [4]. Technology in the form of Mechatronics is a feasible solution to decrease cost of labour and avert wastage of resources [5].

The proposed solution involves the design of an irrigation system that is controlled by an Arduino microcontroller. The controlled element of the irrigation system are the pump and solenoid valves which will be actuated to provide water to the irrigation point (area).

1.1   Mechatronics in Agriculture

Agriculture is one of the oldest industries, dating as far back as the nomadic age. It originally depended solely on human effort, then apprehended animal labour, and then came mechanical advances such as diesel/steam-engine tractors and mechanical tools with hydrostatic power which needed control. The answer to unresolved problems relies on more advances that necessitate the replacement of human intellect to meet the requirements for superior autonomy in more indefinite and unstructured environments. Promising disciplines in this framework include Mechatronics, Large-scale optimization and Complex system automation. Necessity is driving the implementation of information technologies into agricultural technologies, it could be in the guise of a process controller, a machine, or a management and planning system [6].

Technology today plays the role of a feeding hand to agriculture. Elements of Mechatronics, such as actuators and sensors, play vital roles in our farms of seeding, cropping, cleaning, fertilizing and monitoring our vegetation. Today, sensors are applied in detecting colour, ambient light levels, alcohol levels for ripeness, moisture levels and dangerous levels of chemicals including insecticides and pesticides. Different mechanisms have also been designed and constructed to aid agricultural processes, for example, robot arms that nurture the roots of plants and revolving machines to seed, collect, and clean produce, and to regenerate the soil [7].

In contemporary, multifaceted agricultural facilities numerous Mechatronics and embedded systems, such as microcomputers and microcontrollers, are already in application. These autonomous elements are the foundation and building blocks of a modern agricultural complex. The basic of today's modern agriculture is the precision agriculture (PA), where crop production is made more effective using sophisticated control systems. The essence of precision agriculture is essentially the manuring and irrigating by needs and with high precision [8].

Several of the innovations presented to agriculture by the scientific and Industrial revolutions paved the path for a qualitative transformation in the nature of agricultural production. Various helpful effects have been attained by the application and integration of technology in agriculture. It has not just lessened the labour, but it has also decreased the cost of crops by producing massive yield [9]. It has also permitted agribusinesses and farmers to export a large portion of their produce to other nations. Farm exports have permitted farmers to increase their markets and have contributed to supporting a nation's trade balance. There are several factors that affect high yield in crop production, these include: Proper tillage practices, use of high yielding variety, prepare seed bed properly, crop rotation, multiple cropping system, proper seed rate, proper time sowing, balance fertilizers, control of pest diseases and weeds, time of harvesting and proper irrigation. Automated irrigation [10], [11], [12] which this research investigates, is needed to supply the controlled volumes of water to plants at required intervals which helps in crops growth, sustain landscapes, and revegetate troubled soils mostly in dry areas and also during periods when the rainfall is less than average.
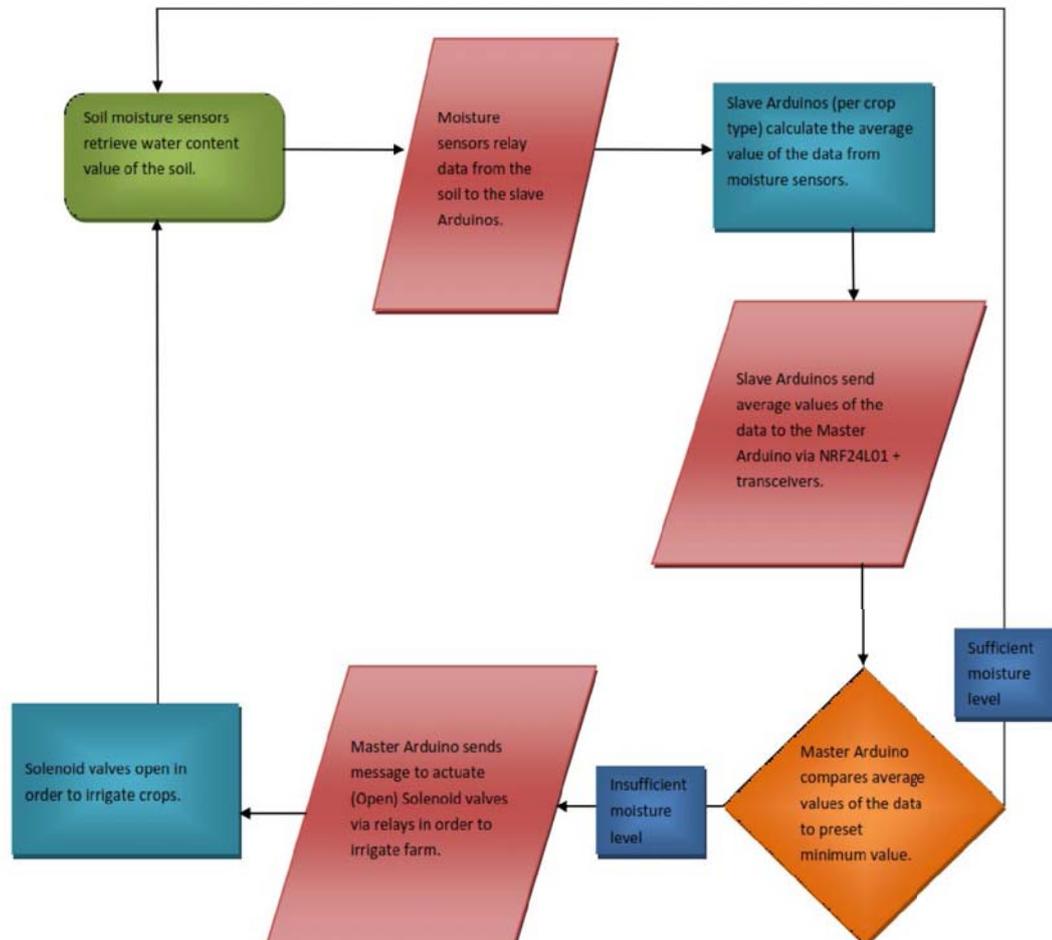
2.   Methodothology

Figure 2: Flow chart of the irrigation system

The electronic component consists of:

❖ The Sensing Module
❖ The Communication Module
❖ The Control Module
❖ The Actuating

2.1   The Sensing Module

This unit is responsible for harvesting the moisture content of the soil at a particular time. The system consists of three sensor unit boxes for the three crop species and each sensor box consists of a network of five (5) Soil Moisture Sensors, an Arduino UNO Microcontroller (Slave Arduino) and a Nrf24L01+ transceiver. The soil moisture is measured using the Probe-type Soil Moisture Sensor. The sensor gives out a value usually between the range of 420 and 1023 based on its architecture and moisture content. This raw data is collected by the Arduino UNO. The microcontroller is then programmed to perform the following actions:

❖ Collect the raw data from each of the sensors; each of the five moisture sensors was inserted close to the root of the plants to obtain accurate data.
❖ Map the data information to a value between 0 and 100%.
❖ Calculate the average of the raw data from the four (4) sensors.
❖ Wirelessly transmit the data to the Master Arduino Mega 2568 via the Nrf24L01+ radio transmitter.
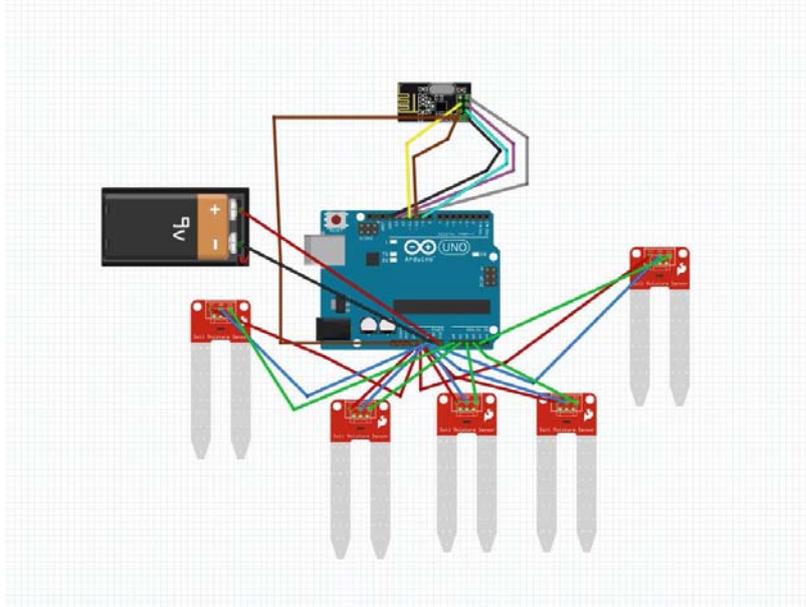

Figure 2.1: Sensing Unit Schematic

The Sensing Units establishes a wireless serial communication with the Master Arduino (actuating unit) via the Nrf24L01+ communication transceivers. Power is supplied to this unit by a 12 Volts D.C. battery.

2.2   The Communication Module

The Nrf24L01+ modules (4 in number) are radio communication devices which consume low power but send data and signals at high frequencies over a relatively long range (100m). This module was chosen because of its networking capabilities and signal rate. The Master Arduino Identifies each transmitting device uniquely via a special character sent along sides the data payload.

Figure 2.2: NRF24L01+ Module

2.3   The Control Module

The control module generates a control action based on the soil moisture level. It consists mainly of an Arduino Mega 2560 microcontroller (Master Arduino), an LCD – 2x16, an Nrf24L01+ transceiver and an 8-channel relay block module all attached to and taking instructions from the Arduino Mega 2560 (master controller). The real time soil humidity data is received by the master Arduino via the radio communicator (Nrf24L01+) module and the microcontroller is the programmed to perform the following actions:

Compare the soil humidity values with a set of ranges;
A – 0 – X% (for insufficient water / dry soil),
B – X – Y% (for sufficient water / moist soil); and
C – Y – 100% (for excess water / soggy soil).

For each of the ranges of soil moisture values from each crop specie soil moisture sensor unit, a unique control action is generated.
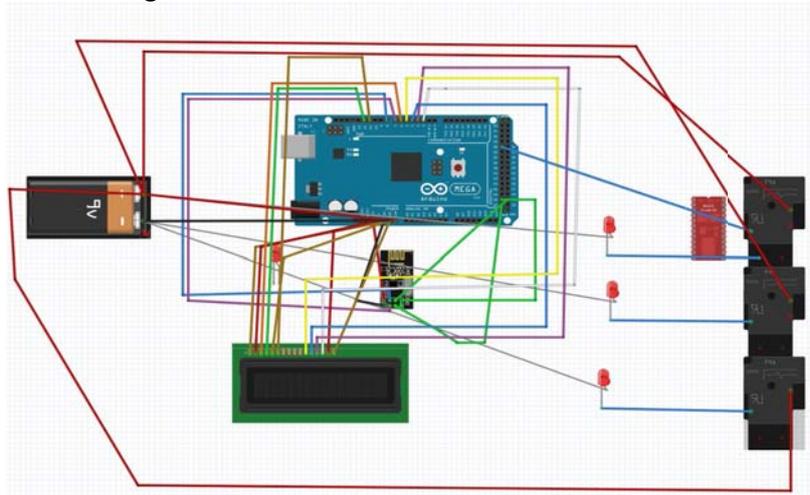

Figure 2.3: Control Module Schematic

This is due to the higher voltage requirement of the Solenoid valves (12V D.C.) represented by LEDs in the schematic above, the 8-channel Relay block was introduced to enable the Arduino Mega microcontroller (which can only give out a maximum of 5 Volts D.C.), control the three solenoid valves in the drip irrigation system. The following actions are taken depending on the range the received average of soil moisture falls within.

Range A – The Arduino sends a signal to open the valve along that particular soil drip line by setting the pin to the relay 'HIGH'.

Range B – The Arduino keeps the solenoid valve is a closed position by sending a 'LOW' signal to the relay pin connected to the corresponding Arduino pin.

Range C – The Arduino keeps the solenoid valve in a closed position by sending a 'LOW' signal to the relay pin connected to the corresponding Arduino pin.

2.4   The Display Unit

The display unit is connected to the Arduino Mega 2560 micro-controller and is used to display the state of the solenoid valves real-time.

2.5   The Actuating Module

This consists simply of an Electromagnetic solenoid valve which is normally pressurized under the gravity potential of the fluid from the reservoir.

2.6   Power Requirements

The system is powered via a combination of an 18V solar panel module and a 40AHr, 12V battery system. The solar panel charges and powers the system during the day and the battery pack takes over at night to recharge the following day in sunlight via the solar panel and solar charge controller.

Table 1: microcontroller and valve requirement.

Component	Quantity	Current Rating (A)	Total Current (A)	Time of Operation per day (Hours)	Energy Requirement (Ah)
Arduino UNO	3	0.2	0.6	24	14.4
Arduino Mega	1	0.5	0.5	24	12
Solenoid Valves	3	1	3	1	3

*Using an approximated value of 30Ah; Minimum battery size required = 30*2 = 60Ah
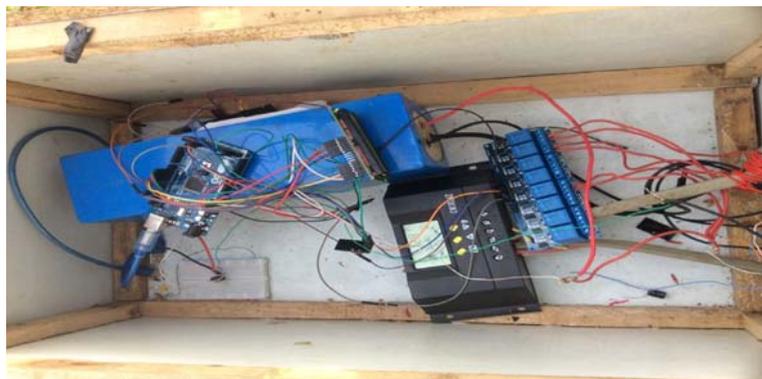
3.   Discussion

Figure 3.1: Brain box of the system which comprises the microcontrollers, battery, relay and charge controller

Figure 3.2: Sensor box with distributed sensors

Figure 3.3: Automated irrigation system

A water reservoir tank of capacity 1000 liters elevated on a stanchion of height 2 meters above the ground is used to store and supply water at the required pressure via gravity to the drip irrigation system when required, as determined by the microcontrollers which control the solenoid valves. The piping design is made up of a 4-meter-long main drip line connected directly to the tank. Along its length lying horizontally on the floor, are three equally spaced drip sub-lines for three crop rows/ridges, each of which holds ten equally spaced drippers to deliver the water directly to the roots of ten crops, controlled by the Arduino microcontroller. Along each drip irrigation sub-line is a sensor box which houses an Arduino Uno microcontroller dedicated to reading analog values of soil humidity from five evenly spaced moisture sensors along a subline. When the soil humidity sensors read values from the soil, the Arduino Uno is programmed to calibrate the values to a percentage range of values between zero and one hundred. The overall average humidity value is then calculated, and transmitted along with a unique identity number (to distinguish each Arduino Uno from the others) via a radio transmitter - NRF24L01+ to the central Master control Arduino Mega. When the Master Arduino reads the average humidity value and identity number from a particular transmitting Uno, it runs the algorithm unique to the crops. the Mega actuates the corresponding solenoid valve open to allow water flow into the sub-line of the transmitting Uno to irrigate the crops for a set amount of time after which it closes.

4. Conclusion

The proposed prototype involves the design of an automated irrigation system that is controlled by an Arduino microcontroller. The controlled element of the irrigation system are the pump and solenoid valves which will be actuated to provide water to the irrigation point (area). The system which was designed and developed by integrating several hardware and software features such as moisture sensor, communication module, Arduino microcontroller, solenoid valve, relay, battery and solar power system has been tested successfully. The designed system was able to accomplish the following:

- ❖ Determine when exactly the soil of each crop needs water.
- ❖ Wirelessly communicate the moisture state of the soil of the different crops to the control module.
- ❖ Deliver a controlled amount of water to the root zone of the crops based on the soil moisture state.
- ❖ Able to run 24/7 on renewable solar energy.

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