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Original Research Article

Design and Development of an Automated Irrigation System Using Internet Services

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Abstract

Food insecurity caused by decline in food production due to shortage of workforce, has necessitated the automation of the various agricultural operations. The study was aimed at the design and development of a prototype drip irrigation robotic system, which used the internet services for its operation (Internet of Things). The robot has a microcontroller, soil moisture and temperature sensors and a water pump. During operation, the robot received the input commands through the soil temperature and moisture sensors. It had the ability to deter the water requirement of the targeted crop, before irrigating it autonomously with the right volume of water. Performance evaluation of the robotic system revealed that it had an efficiency of about 90% and accuracy of about 95% when controlled through the internet. This prototype will help in the production of automated drip irrigation robots, that will preformed effectively in the field.

Keywords: Automated robot, crop production, food security, Internet of Things, sensors.

INTRODUCTION

Irrigation is the artificial means of supplying water to crops, when natural means become insufficient, to meet up their (crops) water requirement. There are several irrigation systems, and each system has its own advantages and disadvantages. Adequate irrigation system enhances food security, as it encourages food production both "on" season and "off" season [1]. Advance methods of crops irrigation have become necessary due to decline in food production, due to lack of manpower and obsolete farming techniques. Food and Agriculture Organization (FAO) states that there is drastic increment in food prices, which is caused by growing human population and food insecurity [2]. Therefore the utilization of autonomous agricultural systems that will aid increment in food production, have become a necessity to alleviate the problems (hunger, starvation, crime, etc.) being caused by food insecurity [3].

Several researchers had designed and developed automated systems for various farm operations, including irrigation operation. Sikorski [4] designed and developed a prototype of an automated plant care system that can irrigate plants in the field, using the laser range finders to locate the targeted plants. Hema [5] developed an autonomous mobile irrigation robotic system that was fortified with a Radio Frequency Identification (RFID) module and Xbee device. They reported that the automated robot can sense and locate the crop in need of water, and then irrigate it autonomously. Likewise, a mobile flowerpot-type which tracks sunlight for its operation was developed by [6] in 2011. The system draws the attention of the farmers when the crops are in dire need of water. Similarly, another group of researchers [7] used a dielectric sensor fortified robot to irrigate on green bell pepper (Capsicum annuum L.). They reported higher efficiency when compared to manually operated irrigation systems. Also, Nogueira [8] developed an automated drip irrigation system for sweet corn production. This system saves about 11% of irrigation water when compared to sprinkler irrigation. To enhance the optimization of agricultural robots, Emmi [9] stated that an automated agricultural robot must be familiar with the field, in order to detect obstacles and communicate effectively with users, hence minimizing damage done to the targeted crops.

Despite the advance researches in automated systems design, some of the robots produced by most researchers had optimization problem. Some of these robotic systems are very expensive and can fail in hostile environment due to laser reflections [5]. An automatic apple trees irrigation system using tensiometers, failed to perform optimally when the tensiometers were installed 30 cm from the drip irrigation emitters [10]. Similarly, robotic system using dielectric sensors was developed by [11], and reported that the dielectric sensors operation was limited in vegetable farming. Additionally, [5, 12] design and developed an automated irrigation robot for crop production, but they were not internet based (IOT) in their mode of operations.

Some researchers [13, 14] had had agreed that in most cases, the basis of agricultural operations autonomous systems consists of four main subtasks, which are: sensor acquisition, modeling, planning, and execution. Agricultural robots to operate effectively in unstructured fields, new technologies and improved intelligence systems must be incorporated into the robotic system [15]. This research is aimed at the design and development of an automatic irrigation system, for irrigating crops in an unstructured environment, using the internet services. The soil temperature and moisture sensors activate the robot, which will then supplied the right quantity of water the target crop, based on the water requirement of the crop. Furthermore, the robotic system is designed to be operated with the aid of an android phone.

MATERIALS AND METHODS

All the steps taken to achieve the production of the drip irrigation robotic system are given in Figure 1.

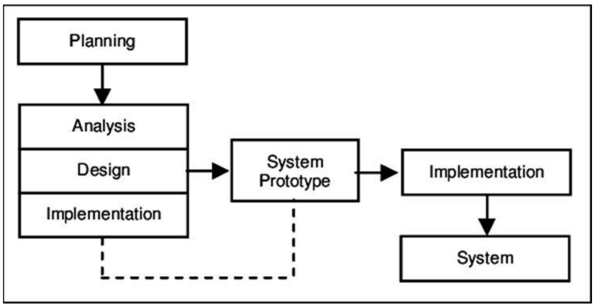

Fig-1: Block diagram of the robotic system

Robotic system architecture and description

The system architecture of the robot produced in this study is shown in Figure 2. This robot was designed and developed to assist farmers in their crop production. . This robotic system can perform drip irrigation through internet of things (IOT) operation (controlled by a GSM module), hence enhancing performance and lowering operational risk of the farmers regardless of the location. The soil moisture content was determined using the YL-69 with Arduino soil moisture sensor which is controlled by a microcontroller. YL-69 soil moisture sensor is made up of an electronic board and the probe with two pads, which detects the amount of water content in the soil [16].

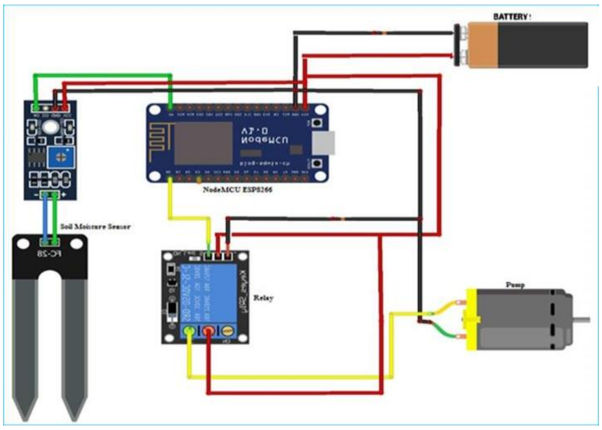

Fig-2: The robotic system architecture

Components used

The robot consists of these basic components: water pumping machine, 4-Relay Module, soil temperature sensor, soil moisture content sensor, NodeMCU ESP8266 and DC battery.

NodeMCU ESP8266

The NodeMCU consists of a firmware that runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and a hardware that was based on the ESP-12 module (Figure 3).

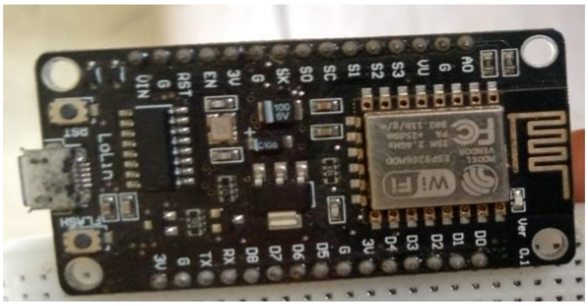

Fig-3: A NodeMCU ESP8266

4-Relay Module

This is a three pins electrically operated switch, which can turned on or off through the aid of a magnetic field generated from the coil (Figure 4). The coil usually has a voltage rating of 12V per channel [17].

Fig-4: A 4-Relay Module

Jumper wire

This can be a single strand wire, with nominal diameter ranging from 1.5 mm to 1.8 mm, which is used for the interconnection in Medium-density fibreboard (MDF) and other internal terminating boards [18].

Breadboard

This is the construction base for the building of electronic circuits (Figure 5). It has several holes into which electronic components (e.g. integrated circuits, resistors, jumper wires, etc.) are be inserted. The holes run in set, and each set is been connected with a metal strip underneath to form a node [19].

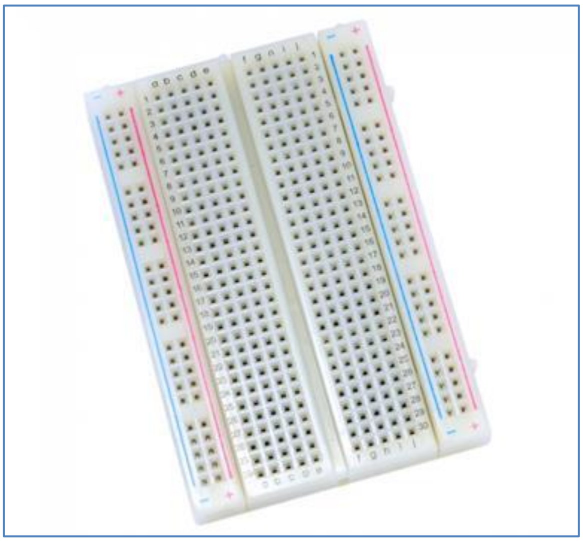

Fig-5: A Breadboard

Water Pump

This device was used to convey (move) the water from the reservoir to the target plant Figure 6. It has the following specifications.

Operating voltage: 2.5 - 6V max
Operating current: 220mA max
Water flow rate : 120 L/H max
Maximum head : 110 mm max

Fig-6: A water pump

Moisture content and temperature sensors

These two devices are inserted in the soil to detect the water content and temperature of the soil. They helped to analyze the amount of water the plant required at a particular time [20].

Battery

A 9 V battery (Figure 7) was used to power the robotic system, and it was connected to the power port of the arduino. All the other electronic components of the robot derived their power from the arduino, similar to the previous design by [12] for mobile autonomous irrigation robot.

Fig-7: A 9 V battery

Programming language used for the robotic system

The Arduino IDE framework using the C++ language and blynk App were used to design and development of the automated irrigation robot. The C++ language was adopted in this robotic development, because it is an elegant, flexible, simpler, safer and object-oriented language, which allowed programmers to develop chains of applications [21].

RESULTS AND DISCUSSION

Robot description

The detailed arrangement of the developed robot during operation is given in Figure 8. During operation, all verified and predicted data sets stockpiled in the Cloud server, can access through the android mobile phone by the user. Hence, the irrigation robot provides a web interface to the user, and it can be controlled remotely through the "ON" and "OFF" icon displayed on the displayed on the smartphone screen.

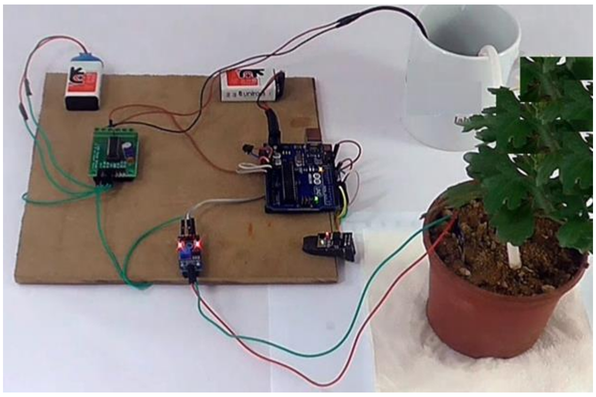

Fig-8: The prototype of the drip irrigation robotic system

Mode of operation

The robot receives the input commands (soil moisture content and temperature) through the sensors, which are transmitted serially to the Pi3 which is edge level processor where K-NN machine learning algorithm employed for predicting the soil condition based on trained data set. Then the control signal sent to Arduino back again for watering the pump. Verified data set and predicted data are stored in Cloud server for farmer's access via their mobile phone. The automated system will be powered by a 9 V battery which will supply DC power to the water pumping machine. The water pump will be activated by the relay module, which will be powered by the 9 V DC power supply. Additionally, the temperature and moisture sensor modules were placed at regular intervals in the field close to the plants. The soil moisture and soil temperature sensors helped to transmit continuous stream of soil moisture and temperature data to the robotic system, through the sensor node which the robot will acts on accordingly [5].

Performance evaluation

The test was carried out on crops planted in buckets (pot experiment), with maximum spacing of 50 cm x 50 cm (which is the spacing of most crops in the field). The robot was tested based on its efficiency (utilization of water) and accuracy when controlled through the internet. It was observed that the robot has an efficiency of about 90% and accuracy of about 95% when controlled through the internet. Results obtained from this study are similar to those obtained by previous researchers. Muñoz-Carpena [11] reported that robot drip irrigation system controlled through the internet was more effective than manual drip irrigation system. Additionally, the works of [8] stated that automated drip irrigation system saved about 11% of water compared to the sprinkler irrigation system.

Compared to existing autonomous irrigation systems, this robot has higher irrigation efficiency through the utilization of moisture and temperature sensors. These sensors help to shutoff off the water pump once specified soil water content and temperature had been achieved. Also this system is light weight, user friendly and ease of maintainability, compared to some irrigation systems that just sent signals (alarm) to the user (farmer) instead of actually irrigating the plants.

Flowchart

The flowchart of the design, development, programming and operation of the automated drip irrigation system is presented in Figure 9.

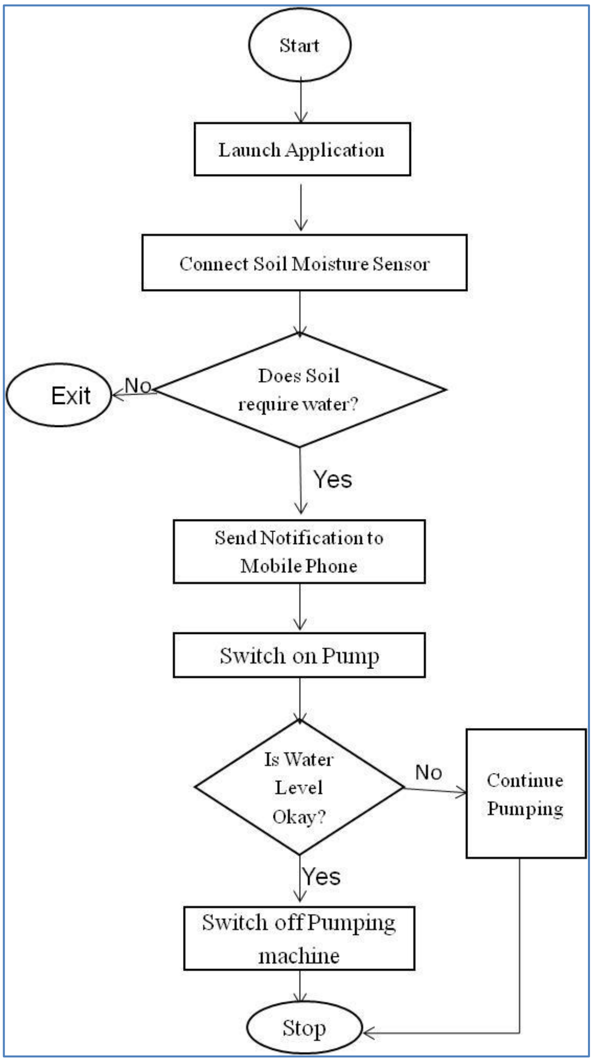

Fig-9: Control flowchart of the robotic system

CONCLUSION

This study was carried out to develop a wireless automated drip irrigation robotic system, to overcome some limitations encountered during manual crops irrigation. This prototype robotic system was able to perform three main functions, which were: determine the water requirement of the crop, sensing the soil moisture and temperature level, and irrigating the crop with the actual volume of water required by the crop autonomously. The robotic system performance evaluation showed that, it was efficient, cost effective and use of web-services compared to most of the previously developed autonomous systems.

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