Development of a Cloud-Based Automatic Irrigation System: a Case Study on Strawberry Cultivation

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***Abstract*—High increment rate of human population brings about the necessity of efficient utilization of world resources. One way of achieving this is providing the plants with the optimum amount of water at the right time in agricultural applications. In this paper, a cloud-based drip irrigation system, which determines the amount of irrigation water and performs the irrigation process automatically, is presented. Basically, water level in a Class A pan is continuously measured via a water level sensor and duration of irrigation is calculated using total amount of level decrement in a given time interval. The irrigation process is initialized by powering solenoid valves through a microcontroller board. To measure the environmental quantities such as temperature, humidity and pressure, an extra sensor is included in the system. A GSM/GPRS module enables internet connection of the system and all the sensor data as well as system status data are recorded in a cloud server. Furthermore, an accompanying Android application is developed to monitor the instantaneous status of the system. The system is tested on a strawberry field in a greenhouse. Currently, it is active for about four months and first observations imply that the system is capable of successfully perform the irrigation task.**

Keywords*—automatic irrigation; internet, cloud, water, strawberry, agriculture

I. Introduction

The world population has seen an explosion with the advancements of the technology in the last decades. As a result of this huge growth in the global population, the required amount of food production is increased. In order to achieve this, new approaches such as hydroponics, vertical farming, biotechnology, etc. are being applied. On the other hand, development of methods for effective utilization of water resources is required because shortage of water supplies, which is one of the leading consequences of emerging climate change, is on the rise [1]. Therefore, it becomes inevitable to include automation and data processing methods in modern agricultural irrigation systems in order to optimize the water usage.

The studies in this area are generally based on indirectly estimating the water need of plants and determining optimum duration of irrigation accordingly. This is accomplished by using daily meteorological data [2], soil moisture sensors [3-8], drainage lysimeters [2,9] or evaporation pans [10-12].

Majority of the automated irrigation system studies use soil moisture data to determine the irrigation amount. For example, the system developed by Gutiérrez et al. consists of soil-moisture and temperature sensors for data collection, a gateway unit for triggering actuators and internet connection, and a web application for monitoring and programming of the system [3]. Their system was tested on a sage crop field and achieved water savings up to 90% compared with traditional irrigation practices. In another work, irrigation scheduling for cucumber is performed through a standalone smart irrigation system with ZigBee and GPRS communication capabilities [5]. The system is programmed to keep the soil moisture above 17%. Irrigation control is achieved through fuzzy logic method which uses sensor data such as soil moisture, ambient temperature, solar radiation and amount of water consumed. Drought stress and irrigation in potted plants are controlled using an automated system proposed by Nemali and Iersel [6]. The system consists of a dielectric moisture sensor, data logger and solenoid valves. In this system volumetric water content of a substrate is measured every 20 minutes and irrigation is controlled according to this measurement. A solar powered and versatile drip irrigation system is developed by Dursun and Özden [8]. Their work involves generating a soil moisture distribution map in an orchard. This is achieved by placing a number of soil moisture sensors and an artificial neural network model. Using this system, unnecessary irrigation is prevented and consequently water and energy consumption is reduced. In a relatively recent work, computer and mobile modules are developed for facilitating irrigation scheduling in the strawberry sector especially during the crop season [13]. The irrigation time within this system is calculated by using a previously built database which contains various agricultural data proven to be affecting the irrigation requirements.

Even though there are various methods for irrigation automation in the literature, systems using evaporation pans featuring cloud connection is not mentioned. In evaporation pan applications, the pan is mounted in a greenhouse and the water level in the pan is observed on a regular basis. At a given time interval, the water loss in the soil is estimated according to the amount of water evaporated from the pan. Conventionally, the water level in the pan is observed with bare eyes and the valves are controlled manually. This method brings some disadvantages such as wasting time and energy.

In this study, a cloud-based automatic drip irrigation system that involves measurement of the water level in a Class-A evaporation pan is proposed. Measurements from a water level

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sensor attached to the pan and an environmental sensor are continuously transmitted to a microcontroller that controls the solenoid valves. Using a GSM/GPRS module, the received sensor data and system status related information are sent to a cloud server. Opening hour of the valves and irrigation frequency are determined by the user. On the other hand, the duration of irrigation is automatically calculated according to the water level decrement in the pan. Also, an Android application is developed to monitor system status remotely and update the water level information in the cloud. Block diagram of the system is provided in Fig. 1. The system components are introduced in Section II. Experimentation of the system on a strawberry greenhouse area is given in detail in Section III. Section IV contains the conclusions and future work.

II. The Irrigation System

The irrigation system involves four main parts which are power & actuator, data gathering, control & internet connection, and monitoring. These units are detailed in the upcoming subsections.

A. Power & Actuator Unit

A transformer and solenoid valves constitute this unit. The solenoid valves are opened when 24V AC is applied to their terminals. Therefore a transformer to reduce the 220V AC line voltage to 24V AC is utilized to power the solenoids. Switching of the solenoids is achieved by sending control signals from the controller unit to the relays placed on solenoid power cables.

B. Data Gathering Unit

This unit consists of a water level sensor, an environmental sensor and a transceiver module. These components are connected to a microcontroller board based on ATmega328P (Atmel Corporation, San Jose, CA).

The water level sensor PN-12110215TC-8 (Milone Technologies, Sewell, NJ) is fixed inside of the evaporation pan to continuously measure the water level. Through the environmental sensor BME 280 (Bosch Sensortec GmbH, Germany) temperature, humidity and barometric pressure in the greenhouse medium are measured. The transceiver module NRF24L01+ (Nordic Semiconductor, Trondheim), allowing RF communication at 2.4 GHz frequency, is used for transmitting these four measurements to control & internet connection unit.

A calibration procedure is required for efficient usage of the water level sensor. Even though the sensor output is claimed to be close to linear in the sensor datasheet, lower test error is achieved when a quadratic model for calibration curve is used rather than using a linear model. For this purpose, when filling the empty pan with water, the output voltage read from the sensor is recorded at every 5 mm of level increment. Next, coefficients of a second order polynomial to these level-voltage pairs are calculated using least squares method.

C. Control & Internet Connection Unit

The components of this unit are real-time clock (RTC) module, transceiver module and GSM/GPRS module.

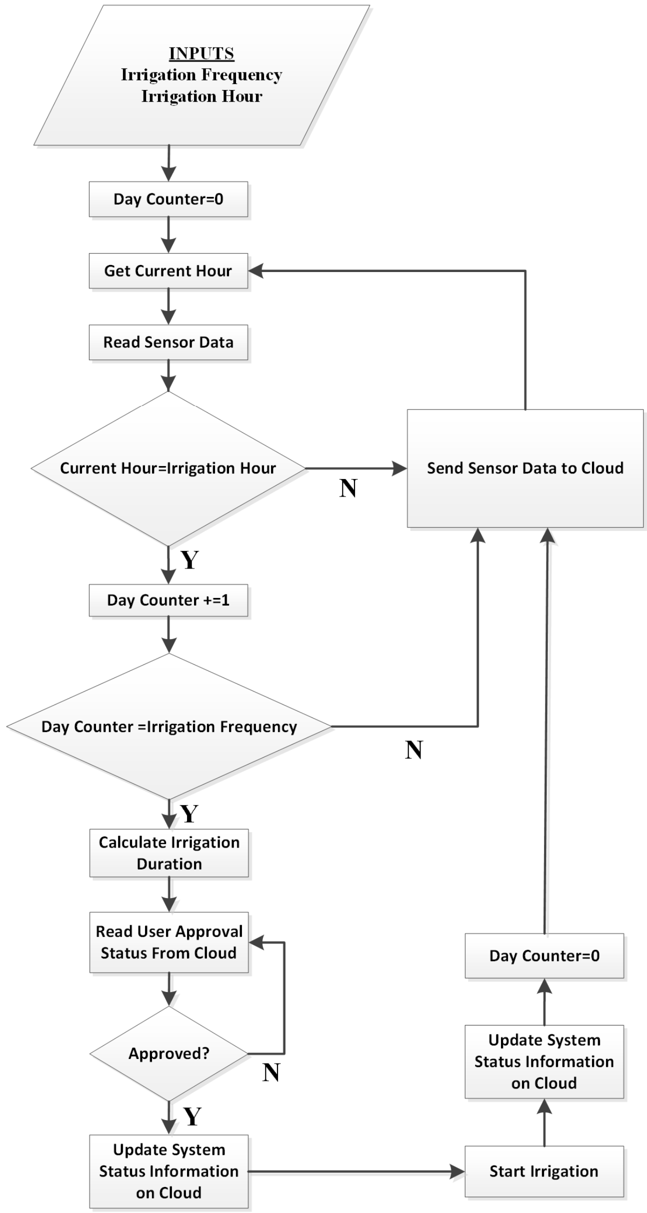

Fig. 1. Block Diagram of the Irrigation System

Processing of the data from these modules and execution of the commands are carried out on a microcontroller board based on ATmega2560 (Atmel Corporation, San Jose, CA).

The RTC module DS 1302 (Maxim Integrated, Sunnyvale, CA) is used for instant reading of local time and date. This information is required to determine when to generate control signal to initialize the irrigation process. Using the transceiver module NRF24L01+, a wireless communication is setup with data gathering unit and the measured data are received. The internet connection of the system is achieved through the GSM/GPRS module, SIM900 (SIMCom, Shanghai, China). A SIM card is attached to the GSM/GPRS module and using a series of AT commands, the sensor data as well as system status related data such as state of solenoid valves (open-closed), date and duration of last irrigation are send to a cloud service.

D. Monitoring Unit

The monitoring unit involves an Android application developed using MIT AppInventor [14]. The application allows the user to check the current status of the system and observe the instantaneous environmental conditions in the greenhouse. Furthermore, it is possible to update the water level information using the application. This may be necessary when the evaporation pan is refilled with water or when the reading from the water level sensor is not accurate enough.

The application screen is divided into four major parts with horizontal red stripes (Fig. 2). The topmost part contains current sensor data. In the second part, water level information as well as measurement date and time information for last two irrigations are provided. Current states of valves, duration and starting time of last irrigation are given in the third part. The valve state information is color-coded where red means valve is closed and green means valve is open. The bottom part is for user intervention. Using the textbox, the user is able to update the water level information. Besides, the overall status of the system is provided in this part. This status may either be *passive*, *active*, or *waiting for user approval*. If all of the valves are closed, the status is *passive*. Similarly, the status is *active* if any of the vales is open. The status is *waiting for user approval* only at the scheduled irrigation time. In this state, an input from the user for the water level is prompted and the irrigation is initialized only after *Send* button is tapped.

III. Application

The system is deployed in a high tunnel area (a kind of greenhouse) inside research fields of Çukurova University, Agriculture Faculty and tested on cultivation of strawberries (Fig. 3).

Two separate high tunnel areas are used in order to test the performance of our system. First one is the experimental area on which the automatic drip irrigation system is installed. Second one is the control area which is irrigated using conventional methods. Due to the agricultural research requirements, each area is divided into four subsections and four different irrigation regimes (i.e. different irrigation durations) are applied to each subsection. In order to calculate the irrigation duration, the following equation is used:

$$t = \frac{E_{pan} \times K_{cp} \times P \times A}{q \times n} \quad (1)$$

where E_{pan} is the cumulative free surface water evaporation at irrigation interval (mm), K_{cp} is plant-pan coefficient, P is plant cover (%), a parameter related with area of plant leaves, A is field area (m^2), q is flow rate from the emitters, and n is the number of drippers in the field [15].

There are four irrigation treatments, designated as Ir50, Ir75, Ir100, Ir125, where the water quantities applied are 0.5, 0.75, 1.00 and 1.25 times the pan evaporation (E_{pan}) measured by the US Weather Service Class-A pan with a standard 120.7 cm diameter and 25 cm depth placed over the crop canopy in the center of the high tunnel. In this way, the best irrigation regime for the strawberry will be understood after harvesting and analyzing them.

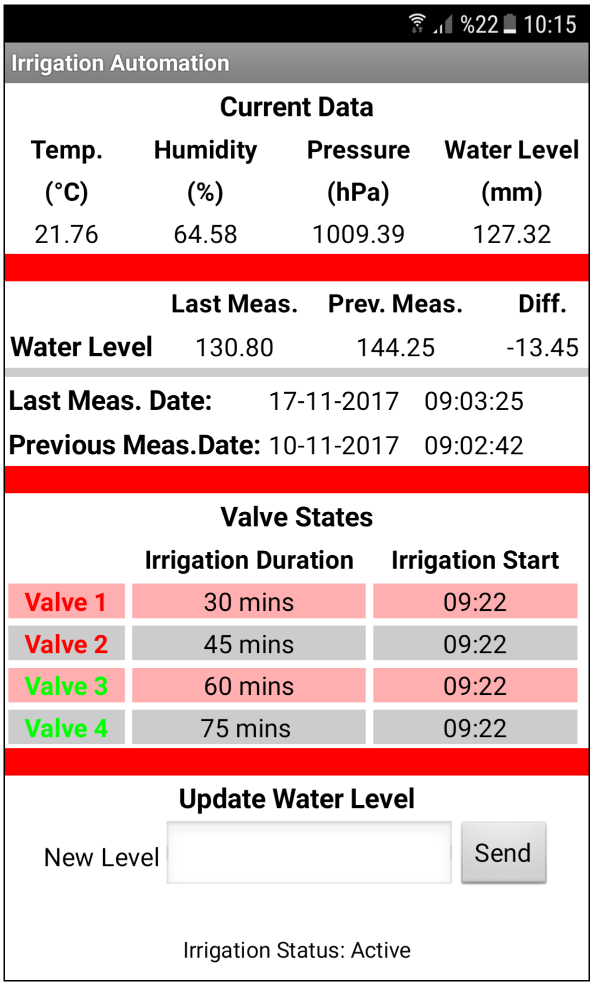

Fig. 2. Screenshot of the Android application taken during irrigation. Valve 1 and Valve 2 are closed. Valve3 and Valve 4 are open.

Currently, the system is active for about four months. According to the most recent observations, the strawberry plants in experimental area and control area are in equal states in terms of growth, plant health and soil conditions.

IV. Conclusion

An automatic irrigation system based on microcontrollers connected to a cloud service is described and its application to a strawberry field is demonstrated here. When compared to its counterparts, our system has some novel features. First of all, the optimum amount of water required for irrigation is automatically computed. This computation is based on the water level decrement at a certain amount of time in the evaporation pan. Usage of optimum water amount prevents the plants from not only drought stress, but also the over-watering related fungal and bacterial diseases. Besides, this system has an accompanying Android application which makes it possible to remotely check the current system status. With this system, possibility of human-related errors as well as reserved labor time for irrigation task are minimized. Furthermore, usage of

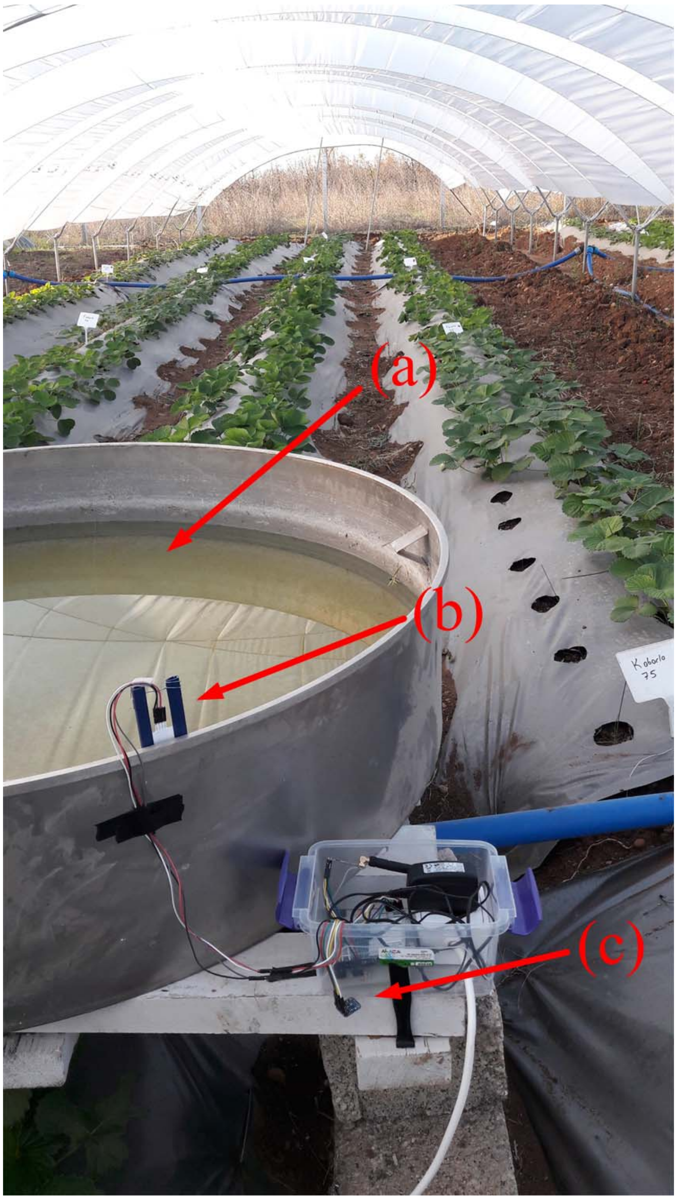

Fig. 3. Data gathering unit inside the greenhouse. (a) Evaporation pan, (b) Water level sensor, and (c) Environmental sensor.

optimum amount of water for best crop quality definitely makes contribution to modest water consumption on earth.

The entire system related information such as sensor values, total evaporation between two consecutive irrigations, irrigation dates, times and durations are stored in a cloud server. Using these values, a statistical model to estimate the total evaporation may be constructed in the future. Also, currently the system is on-grid all the time and in case of a power outage, sensor measurements are halted and internet connection is lost. Therefore, supplying electricity to the system with batteries that are charged through solar panels is among our future plans. More sensors such as anemometer and soil moisture sensor are going to be added to the system as well.

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