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IFAC-PapersOnLine 49-16 (2016) 381–386

Application of Integrated Control Strategy and Bluetooth for Irrigating Romaine Lettuce in Greenhouse

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Abstract: A greenhouse usually is a costly facility that can offer better environment for crops. Thus, to efficiently operate the facility in greenhouse is important for farmers. This study compared conventional timer control and soil moisture control method with an integrated control strategy (ICS) in wireless irrigation that consisted of microcontroller, programmable logic controller, weather sensor, soil sensor and Bluetooth module. Two two-week field experiments were conducted to grow Romaine lettuce and Red lettuce in greenhouse. Results showed plants in test group (with ICS) had higher performance in plant height, leaf number, fresh weight and dry weight. A statistic ANOVA indicated significant different in mean between the two groups (test group and check group). Result of evaluation for electricity and water usage also presents the ICS could save 90% of the electricity and water usage when compared to the timer control method.

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Keywords: Bluetooth, Integrated control. Irrigation, Romaine lettuce, Wireless control

1. INTRODUCTION

Greenhouse offers a protection and a better environment for crops so as to improve the quality and yield of the crops. It has been applied in horticulture especially for off season production and for culturing high quality crops. Greenhouse usually is a high cost facility. Thus, how to use the facility more efficiently is important to the farmers.

Meanwhile, to save wiring cost and hardness as well as to obtain more efficient control, wireless sensing networks (WSN) are applied recently in open field and in greenhouse (Wang, et al., 2006). The WSN technologies includes point-to-point communications, point-to multi-point communications, in short range, such as Bluetooth and ZigBee; or multi-hop wireless local area network (WLAN) in mid-range, and cellular phone systems, such as GSM/GPRS for long-range. Bluetooth is a global wireless communication standard that connects devices together over a certain distance usually 10 m to 100 m. Because of its advantages of low power, easy to use and low cost, it was built into billions of products on the market today and connected the Internet of Things (Bluetooth, 2016).

A Bluetooth device uses radio waves to connect to a phone or computer. A Bluetooth product contains a tiny computer chip with a Bluetooth radio and software that makes it connect. When two Bluetooth devices want to talk to each other, they need to pair. Communication between Bluetooth devices happens over short-range, ad hoc networks known as piconets. The network ranges from two to eight connected devices. When a network is established, one device takes the role of the master while all the other devices act as slaves. Piconets are established dynamically and automatically as Bluetooth devices enter and leave radio proximity (Bluetooth, 2016).

Among researchers of using Bluetooth in agriculture, Lee et al. (2002) used Bluetooth, DGPS, and load cells to transmit moisture sensor data to host computer and create a silage corn yield map for a site-specific crop management. Kim et al., (2006a) developed a WSN irrigation system that collected soil and weather information then wirelessly transmitted to a base station by Bluetooth antenna. They also applied the Bluetooth radio module along with a self-propelled linear sprinkler system with a programmable logic controller (PLC) to maintain a variable rate water irrigation (Kim et al., 2006b).

Sun, soil, and water are important for crop growth. How to maintain a proper water supply for crop is crucial in crop production, quality maintenance, and water conservation. Among many kinds of irrigations, drip irrigation has been accepted because of its efficiency in water saving and control precision.

Hsieh et al, (2010) used drip irrigation for cherry tomato in greenhouse. Results showed a reduction of the fruit cracking ratio and an increase of total soluble solids when plants were irrigated with little amount of water. Jou et al.,(2015) applied PLC and environmental sensors to control drip irrigation system for pot plants in semi-closed type greenhouses. The environmental conditions include solar radiation, temperature and relative humidity. Chen et al., (2015) compared fertigation (drip irrigation with fertilizer) and traditional furrow irrigation with fertilizer for Eustoma plant. Result shows fertigation could benefit both in cut flower quality and saving water and fertilizers.

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Peer review under responsibility of International Federation of Automatic Control.
10.1016/j.ifacol.2016.10.070

Water can be supplies based on time by using a timer. Conventionally famers water crops on morning or afternoon. Water also can be supplied by its CWSI (Crop water stress index) of the crop (Idso et al., 1981a). CWSI uses temperature differential of leaf and air vs. air vapour pressure deficit (VPD) to represent soil moisture conditions conductive to the maintenance of potential evaporation. Idso et al. (1981b) have suggested that such a relationship can be the operational criterion for irrigation and later it was tested in field by Geiser et al. (1982). In order to use CWSI, the water-stressed baseline and on-water-stress baseline need to be calibrated first. These calibration curves depend on crop variety and need follow several processes to avoid measurement error (Gardner et al., 1992). Because the key factors of CWSI are temperature and soil moisture, it would be simpler to measure air temperature and soil moisture for irrigation decision without using CWSI calibration curve.

Environment control is a key issue to greenhouse which can offer better microclimate for crops. Basically temperature, humidity and radiation are three major factors controlled in greenhouse by fan, shading net and other facilities. These factors can be controlled by independently by using single senor and setting upper and lower threshold. But, generally, these factors are not independent, therefore a better control strategy should consider their interactions. Some researches named this integral control as intelligent control because the controller senses the multiple environment information and make multiple decisions with a combined algorithm. In control model, this is a multiple inputs and multiple outputs type. The control algorithm can be adaptive that sensing the needs of crops in real time and set the output to meet the requirement. Or, we can set the output with prior knowledge on input conditions so as to skip the physiological model that usually is a time-consuming task.

Therefore, this study integrates environmental sensors, wireless devices, PLC, and drip irrigation system to consist of a wireless irrigation system (WIS) that can be used in greenhouse. To be specific, the objectives of this study are as follows:

1. to initiate the wireless irrigation system (WIS) with a Bluetooth module;

2. to develop an integrated control strategy (ICS)for drip irrigation by considering air temperature, relative humidity, solar radiation, and soil moisture;

3. to compare the proposed ICS to conventional irrigation approach (timer control or soil moisture control) for Romaine Lettuce (*Lactuca Sativa*) and Red Lettuce (*Loollo Rosa*) to explore the effects on their production;

This study tested Bluetooth and PLC with ICS, timer control and soil moisture control approach for plant irrigation. It tries to find a better water and energy using method for further application in greenhouse or field.

2. MATERIAL AND METHOD

2.1 Environment sensing unit and irrigation unit

To obtain the microclimate information, a temperature and relative humidity sensor (EE-10, Elektronik), a solar radiation sensor (JLP02-TR, TOHO), and a four in one module (JSMHP, JETEC) for soil moisture, soil salinity, soil temperature, and dielectric constant are used with a microcontroller (Mega, Arduino). Calibration equation was calculated from the sensor specification and applied in control strategy running in microcontroller and host station (a personal computer, Fig. 1) so as to transfer electrical signal (such as, voltage) to physical unit (for example, ℃).

Environmental information includes air temperature (T) and relative humidity (RH), solar radiation (S) in greenhouse, and soil moisture (M).

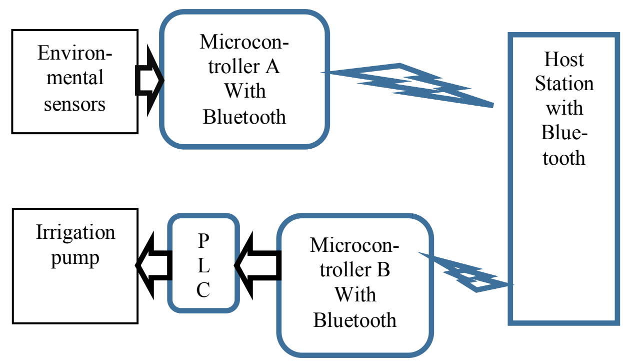

Fig. 1 Schematic of the wireless irrigation system (WIS)

For irrigation unit, a drip irrigation system (Youcan-agritech, Taiwan) was used which consisted of water tank, pump, valve, nutrient tank, and ratio adjustor. The water was pumped to drip nozzle thru main pipe and micro pipe, and finally to the plants. The water amount can be adjusted by number of nozzle, lateral distance of nozzle, and working duration of pump (WDP). An experiment was conducted to record water amount and soil moisture change with WDP in 5, 10, and 15 minutes parameters. The results are shown in Figure 2 and have the regression between WDP and soil moisture change as follows:

$$Y=1.2717X \quad (1)$$

X: working duration of pump, WDP (min)

The equation is available only for the soil below saturation condition.

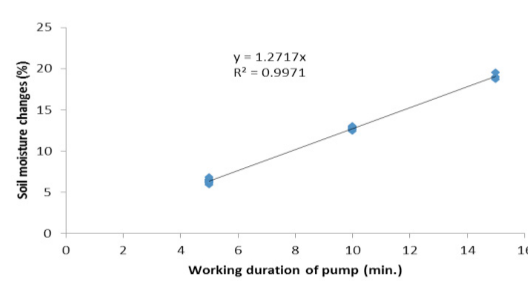

Fig. 2 Working duration of pump versus soil moisture change

2.2 Control strategy

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