Hydroponic system with automatic water level control based on Arduino

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***Abstract*—Hydroponics is a method of growing plants without soil. As it offers several advantages, especially in locations with varying limitations, it has become a widely-adopted technology in both developing and developed countries all around the world. In this research, a low-cost hydroponic system with an automatic water level control system is proposed. A low-cost, open-source microcontroller (Arduino) with an ultrasonic sensor is used. With the ability to detect the water level, the system could decide on when the pump should be turned on/off. This prevents the pump from continuously working and, thus making the process more energy efficient. The additional feature of leak detection is also introduced to the system. The system is developed and evaluated, and results show that the developed system has potential energy saving of around 93% compared to that of a conventional hydroponic system.**

Keywords—hydroponic, Arduino, control

I. Introduction

Hydroponics is a well-known method of growing plants without soil and using only mineral supplement solutions in a water solvent. The growing interest globally toward hydroponics systems can be attributed to its several advantages. First, due to its simplicity in cultivating plants without soil, hydroponics has been quickly adopted in places where conventional agriculture is impossible, such as those with adverse soil conditions and those with limited areas for agriculture (e.g., large cities). Second, with proper cultivation, especially when the amounts of nutrients supplied to the plants are maintained properly, growth has been reported to be faster than that of traditionally grown plants [1–3].

The promising results of hydroponics have given rise to the development of a new direction of agriculture in which technology is introduced to improve the yield. In many countries, high-quality vegetables and fruits have been produced by the technologically-driven and precise control of the environment, and this has been made available as a commercial product [4]. Additionally, a greenhouse environment control system using an environmental control system has also been reported [5].

Studies on hydroponics have progressed well, with new findings and approaches being reported annually. Admittedly, the major drivers are developed countries that developed systems with improved sophistication using advanced technologies. At the same time, though lesser in number, researchers from developing countries, such as Ecuador, Malaysia, and India, have also contributed to research in this field [6–8]. Their focus, however, is different. Considering the cost of the system, developing a low-cost approach that maintains a high yield has been one of the major targets of such studies.

In relation to the above-mentioned studies, the current research aims to develop a low-cost hydroponic system with the ability to maintain the water level in the grow tray using a simple microcontroller-operated mechanism. The ability to control shall be achieved by turning the pump on/off depending on the state of the water level. This way, the pump does not need to run continuously, unlike the conventional hydroponic system. Therefore, the proposed hydroponic system has the potential to save energy as well.

II. LITERATURE REVIEW

A. *Hydroponics and its applications*

Hydroponics is a method of growing plants without soil. When growing plants in soil, water makes the nutrients in the soil soluble and oxygenates the plants' roots. In hydroponics, the supplements are infused directly into the water. In the most abstract sense, a hydroponic system requires a supplement-rich water supply, a method for oxygenating the water supply, and a way to transport the water to the plants. As supplements can be costly, a common hydroponic system is recirculating the water supply. Researchers from all around the world have reported the implementation of a hydroponic system to cultivate tomato [9–11], lettuce [12,13], strawberry [14], and others.

There are six main types of hydroponic systems, and they differ based on the manner by which the system conveys water/moisture, nutrients, and oxygen to the plants. In the current research, the nutrient film technique (NFT) [15] is used in the hydroponic system. In an NFT hydroponic, a pump continuously forces the nutrient solution onto the grow tray and streams the solution over the plants. Then the solution drains back to the reservoir through the downward channel. Aside from the ease and economic advantages of construction, the NFT is also known to use little to zero amount of growing medium and employ water recirculation, which leads to water saving. However, the system is susceptible to pump failure and power outages. Additionally, the main challenge is maintaining the proper flow rate or the water level so as to avoid nutritional problems for the plants [16]. Finally, the NFT is known to be unsuitable for large and heavy plants.

B. *Automatic control of a hydroponic system*

In a hydroponic system, using precise control is necessary to produce high-quality plants. The parameters to be controlled vary greatly and many studies have reported controlling the chemical aspect of the plants [9], the water or the hydroponic liquid [11], and the pH level [6,8,12]. By utilizing an open-source microcontroller (Arduino) integrated with several sensors, many efforts toward designing a low-cost hydroponic system aimed for implementation in developing countries have also been reported [6–8].

III. METHODOLOGY AND DEVELOPMENT

A. *System design*

In this research, an Arduino-based automatic water level indicator and controller is developed. Two main functions are incorporated into the system: 1) automatic water level control and 2) leak detection.

The automatic water level control is achieved by utilizing the ultrasonic sensor for gauging the distance/water level. This information is then used by the microcontroller to control the on/off state of the pump that supplies water to the plants. The fundamental principle of ultrasonic distance is based on the echo principle, and the obtained data are the travelling time of the outgoing and incoming sounds in relation to the starting point. Following a formula, the distance can be obtained. This process is carried out in the Arduino in order to precisely control the water level. If the water level is low based on processed data obtained from the ultrasonic sensors, the system is then commanded to turn on the water motor pump by the use of a relay. In this way, the water level in the grow tray can reach the desired level automatically.

Meanwhile, the function of leak detection could be achieved by utilizing a flow meter, which is positioned at the outlet of the water-supplying hose. The information is then fed to the Arduino and displayed on an LCD screen.

The whole flow chart of the proposed system is given in Fig. 1. The control of the system consists of a simple two-level measurement and decision-making process. First is the water level, *h*, which determines the on/off state of the water pump. Subsequently, the flow rate data are also taken, which determine if a leak occurs or not. If a leak occurs, the flow rate must drop to less than 20 liters/hour and when the system senses this, the buzzer will turn on, notifying users of a potential system breakdown. Otherwise, the system runs continuously by returning to the beginning.

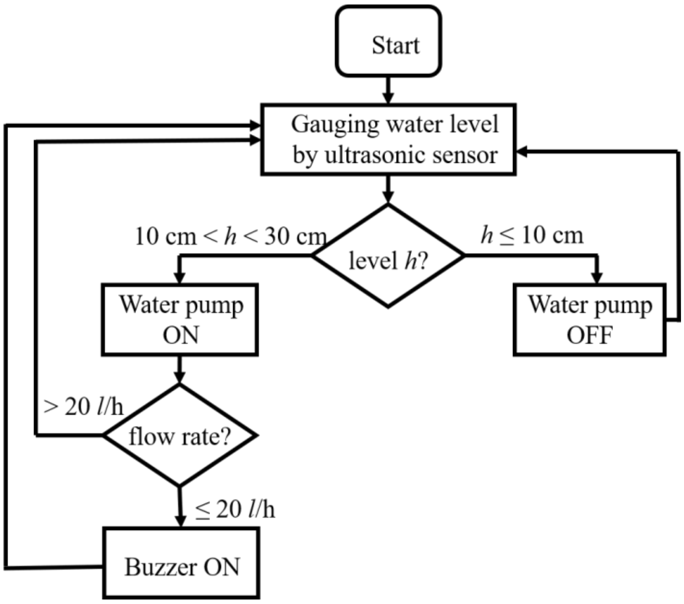

Fig. 1 Flow chart of the proposed system

B. *System development*

Having laid out the system design, the next step is to develop the system. The proposed schematics of the whole system is given in Fig. 2 below. The system shall consist of the water reservoir and a grow tray in which the plants are to be placed. A submersible water pump is placed inside the reservoir so that water can be supplied continuously to the grow tray. A small outlet is made at the bottom of the grow tray, which allows a path for water return and recirculation. The ultrasonic sensor to gauge the water level will be placed on the top, facing toward the water surface. The flow sensor is placed at the outlet of the water supply, which makes it possible for a continuous measurement of the flow rate.

The components utilized for the system development are as follows: 1) Arduino Uno as the microcontroller, 2) ultrasonic sensor HCSR04, 3) flow meter, 4) buzzer, 5) single-channel relay module, 6) submersible water pump, 7) LCD screen, and 8) other components, such as breadboard, wires, and resistors.

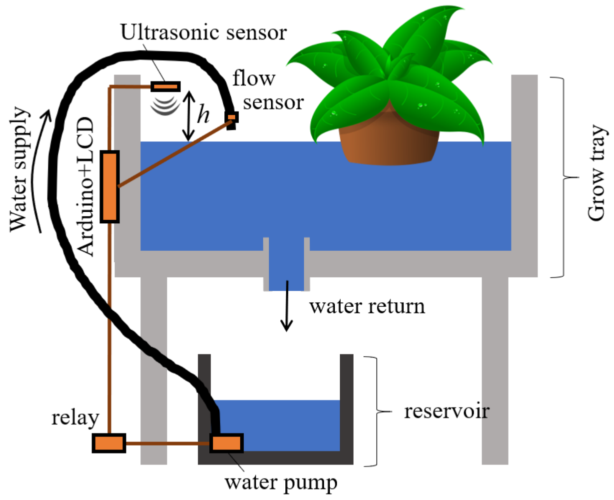

Fig. 2 Schematic of the proposed hydroponic system

IV. RESULTS AND DISCUSSION

The photo of the developed hydroponic system is given in Fig. 3. Lettuce was selected as the test plant. The grow tray was made with an acrylic material, allowing users to visually monitor and validate the water level by themselves. Based on the observation, the developed system worked well, and the data are displayed on the LCD according to the conditions, as depicted in Fig. 4.

Fig. 3 Photo of the developed hydroponic system

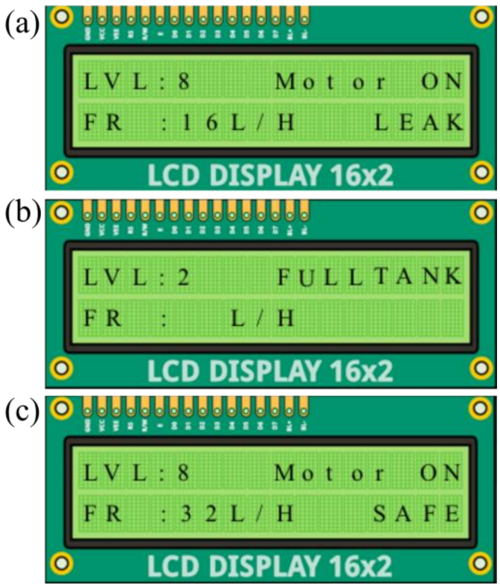

Fig. 4 LCD screen images of the developed system under different conditions

When the water level in the grow tray is near empty, the system allows the pump to switch on via the control of the relay. Fig. 4(a) shows the LCD display for such a condition. In addition, the water hose is pinched, imitating the condition of a leak with a slow flow rate. This was shown correctly on the display (Fig. 4(a)). The buzzer made a buzzing sound as designated. After a while, when the water level is almost full (< 10 cm), the system will switch off the pump. The condition is correctly displayed in Fig. 4(b). Finally, when the flow rate is back to normal (around 32 liters/hour), the LCD displays the reading as being “SAFE” (seen in Fig. 4(c)).

In the experiment, the system was run for one hour and then observed. The pump was observed to be in the off state most of the time, only switching on when the water level was deemed low. In one hour, the pump worked only for four minutes, translating to 1.6 hours each day. From the perspective of energy consumption, this correlates to a significant saving in energy consumption as compared with a conventional hydroponic system with a pump running continuously for 24 hours. With a 15 W water pump, the difference in energy consumption by the pump alone is shown in Fig. 5. As can be seen, the developed system has the potential to cut the energy consumption by around 93%.

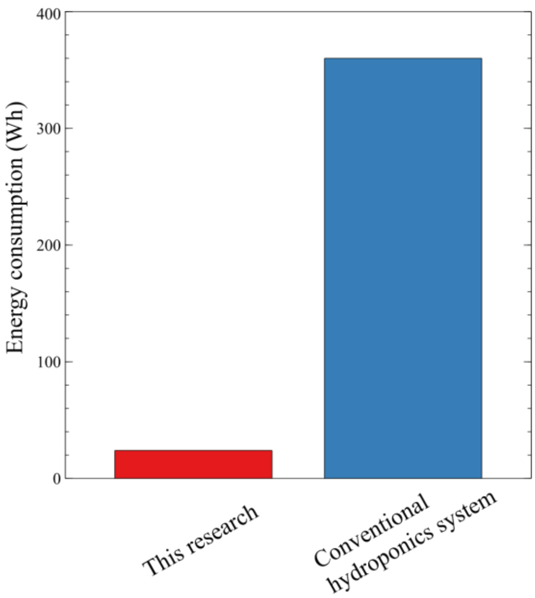

Fig. 5 Comparison of the energy consumption rates between the proposed system and the conventional hydroponic system in one day. Data are calculated by taking into account the energy consumption arising from the 15W pump alone

V. CONCLUSION

A hydroponic system with the ability to control water level automatically was successfully developed. As an additional feature, the flow rate was also measured continuously to detect any condition of leak that can be detrimental to the system. The developed system was evaluated and deemed to work well as per the system design. Furthermore, the energy consumption was also evaluated, showing a potential saving of 93%. In future works, a performance evaluation for a longer-term operation under real conditions must be performed. Additionally, a more thorough evaluation of energy consumption is also needed to justify the performance of the proposed system even further.

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