Smart Home Garden applying Hydroponics

Arijit Sengupta, Shuvam Chakraborty
Dept.of Electrical and Computer Engineering
University at Albany
{asengupta, schakraborty}@albany.edu

***Abstract*—Smart home appliances have started becoming very popular for the last few years because of ease of automation employing smart phones and other intelligent system as master devices. With the growing technological development there has been a significant increase in demand of sustainable technologies to achieve significant reduction of vital natural resource usage. Following the same direction this project aims to develop a low-cost and low-power consuming Smart Garden using Raspberry Pi as the control interface. Hydroponics garners interest because of its efficiency and environmental sustainability. 90%less water is used in hydroponics systems than in soil, no pesticides are needed which are great for ecosystems. Thus, this project proposes a design for smart home garden using hydroponics that implements ready-to-use, energy efficient, and cost effective devices. Raspberry Pi, is integrated with multi-sensors such to help sense and mitigate adversarial weather conditions. This proposed system managed to reduce cost, minimize waste water, and reduce physical human interface as well.**

***Index Terms*—Hydroponics, Raspberry Pi, Low power system, sensors, cost efficent**

I. Introduction

In recent years, the demand of building automation system increases especially in offices and households. Generally, it is because automation helps reducing consumption of electricity, decreases the wastage, uses less manpower, and helps in energy saving. Automation system that is implemented at home is known as home automation. The home automation term is referred to the automation system that can integrate household activities which include sensors to read input condition and centralized the control of electrical appliances. The examples of implementation of automation system at home include home surveillance system, watering plant system, baby monitoring and others.

Smart garden is a fairly explored area of application of modern cyber-physical systems exploiting recent advances in IoT(internet of things). In a smart home garden system the plethora of sensors that regularly monitor the parameters essential for plant growth like temperature, soil moisture, light, soil pH level are what makes the system smart.Different embedded processors are used to provide the interface between the user and the physical sensor and other devices.

Currently, there are a lot of gardening and irrigation systems in the market which are operating in automation system. Nevertheless, the equipment used is very expensive and it is not worth to install the system in a mini home garden. The irrigation system that has been developed by many researchers need a complex and highly priced computer to monitor the plant growth Our smart home implements *Hydroponics* instead of traditional irrigation models. *Hydroponics* is the process of growing plants without soil as a primary source of nutrition. The plants receive nourishment through mineral nutrients dissolved in water. Hydroponic systems implement different types of inert media to support the plants, such as rock-wool, coconut fibre, river rock, Styrofoam or clay pellets[1].

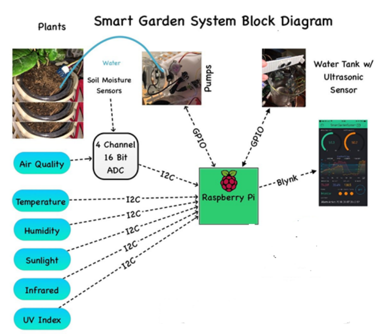

Fig. 1. Example System Diagram[10]

We can readily point out the attributes for which hydroponics has become the choice over the traditional smart garden systems is:

- Water requirement is 8-10% of traditional irrigation system, since water can be conserved and reused depending on requirement.
- No pesticide is required for plants.
- About 20% less space is required for the set-up.
- It is way less atmosphere dependent that traditional systems.

II. Motivation

The project aims to achieve the following:

1) *Monitor essential factors for plant growth* In this step we should be able to capture granular data for the vital components of plant growth like temperature, humidity, light, pH level of the nutrient solution of growth medium.

2) Designing resource efficient system While talking about resource efficiency, the two primary one's are water and

electrical power in our scenario. One of the primary aims are to design an automated system that helps reduce water and power usage significantly.

3) Precise control of weather conditions With all the sensor data collected from various nodes, the system control design should be able to actuate accordingly to mitigate the variations in ambient weather condition of the plant system.

4) *Analysis of weather data*: As we are deploying sensors to measure various parameters, those collected temporal data can be analysed to predict an optimum weather condition for the plant growth which can be based on the climate variation of that region. For complete generalization, a longer period of weather variation information is required.

III. Proposed Model

A. Weather Monitoring System

Precise and granular level monitoring of factors such as temperature, water level of the growth medium, pH level of the water and nutrient solution, air quality, light intensity is required to ensure that user can take necessary action to maintain suitable atmosphere for the system.
Figure 1 depicts an exact block diagram realization of the system, where we can see the corresponding actuators for each sensor connected via a controlling unit which is in-evidently the micro-controller, Raspberry-Pi in our case.

Every sensor measures each weather component essential for plant growth and the data is transferred to the micro-controller. The micro-controller analyzes the data and decides the actuation depending on the threshold values and critical points set by the user while setting up the system. Extra care should be taken in this part of the system, as depending on which is used to grow in this environment, threshold values of parameters should be minutely defined and this part of the system should be easily re-configurable. This analysis triggers the actuators following the condition set in the system design to get the system back to stable condition and when it reaches any critical condition user will be notified about that instantly.

For instance when the temperature sensor measure is way too high an axial fan will be turned on to reduce the temperature, or when light sensor measure goes below 1250 LUX per square meter which is not enough for growth of plants, LED will turn on. Though most important of them all is maintaining water level and pump-in or pump-out the excess water using an EZO pump and bi-directional solenoidal valve to keep the concentration of nutrient mixture in the growth medium in a tolerable limit.
For outdoor application, a hard bound control of air quality and temperature is required since these two essential factors vary way too frequently and vastly compared to others. In case of an indoor set-up, these can be controlled with

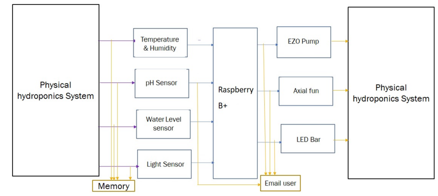

Fig. 2. Block diagram for Smart home garden system

comparatively loose bound.

B. Data acquisition and Analysis

The continuous monitoring of the system provides us with data that helps us with analysing the optimum weather condition. The system is modelled in a given time frame say one hour, if the number of transitions in parameters are minimum(i.e., variance is minimum if we treat the data set as a discrete random variable), average value of parameters for that time period gives the optimum result for the day.
Moreover if the data is analysed for a long term using the similar method proposed above, it can provide a comparative result of the climate and effect of its variation on plant growth. We will try to include a similar comparative result for optimum plant growth depending on data available to us. The following block diagram in figure1 depicts a very high level view of the underlying system.

IV. IMPLEMENTATION

In this section we will specify the sensors and the actuators that are used to counteract the measure provided by the specific sensors.

A. Temperature & and humidity control:

The temperature and humidity sensor DHT11[6]data will be captured every minute(this interval can be changed as per requirement). The primary actuator that works depending on this sensor data is axial fan. Whenever temperature reaches more than 25 degree Celsius or if the humidity reaches over 60% the axial fan will turn on to mitigate humidity or reduce temperature till it reaches optimal values.

B. Water level and Ultrasonic sensors:

The water level and ultrasonic sensors are used to maintain the water level which in turn controls the concentration of nutrients in the growth solution[8]. The tolerable limit of water level is fixed between 5cm to 14cm. The ultrasonic sensor measures the distance of water from the sensor base using the formula mentioned in equation 1

$$D = 0.5TC, \tag{1}$$

where C is the sonic speed and T is the time taken.

The ultrasonic sensor reads the water level input and if it is below 5cm it energises the solenoidal valve to allow flow of water inwards through the EZO pump. Once it reaches

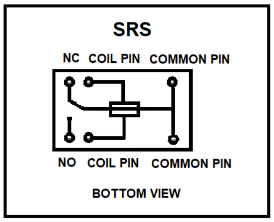

Fig. 3. Relay Module Pin Diagram

the optimal value, the pump stops. The photoelectric water-level sensor[7] acts as a secondary level of safety which has higher precision and if the water level goes to 14cm, the photo-electric sensor comes in contact to the fluid immediately changing sensor value to high which triggers an alarm to warn the user and the valve is reopened to flow water out.

C. Light sensors:

The light sensor[9] employs I2C protocol to communicate with raspberry pi. The light intensity data received from the sensor is used to control brightness of the LED Bar. Intensity data received from light sensor is an unsigned 32-bit integer which is converted to Integer and multiplied by an scaling factor of 2.25 which in turn controls the brightness of LED bar via a PWM module to help realize gradual increase or decrease of brightness.

Due to the complexity in integrating the light sensor which uses a paid API and requires Circuit-Python, a photocell was used instead for the implementation of the circuit. The range of the raw data for a photocell is 0-255 and as per calculation, the value of 190 corresponds to the requisite 1250Lux needed for this circuit.

D. pH sensor:

The pH sensor is used to check the pH level of the nutrient solution for plant growth. Though its data query interval is much longer than other regulating parameters.

Every time a parameter is changed to such extent for which the system needs an actuation, user will be notified about the change. In case of a pH level mismatch the user will get regular warning until pH is changed to a tolerable limit. Furthermore every actuators axial fan, EZO pump, solenoidal valve has provision for manual override using toggle switch in case of system failure.

E. Actuators:

The three elements monitored through sensors have a corresponding actuator attached to it. The temperature and humidity sensor has an 12V Axial Fan actuator to it, the photocell is associated with an active buzzer and the ultrasonic water-level sensor has an EZO pump and a two-way solenoidal valve attached to it.

A relay module shown in Fig. 3 is attached to the circuit which gets activated when one of the sensors go off and starts the corresponding actuator.
Generic relay modules are depicted as a single pole single throw relays where coil needs the activation voltage, which is 5V for SRS-5V relay used in our set-up, normally closed(NC) pin requires output voltage to be controlled and output is generated from the common pin. SRS denotes that the relay used in set-up is a double pole single throw relay, which has two different output pins, facilitating multiple device control.

All the actuators require a 12V DC supply to function, hence the same had to be connected to the NC pin of the relay module in order to get the output from one of the common pins. The coil pin needs a 5V DC supply to activate the relay module but the GPIO pins can only supply a limited 3.3V as its HIGH output. Hence a voltage-divider circuit was constructed separately such that the coil is supplied a voltage around 3V from the circuit and whenever the GPIO pin turns HIGH, it adds to the circuit supply and makes the voltage supplied to the coil pin as 5V to activate it.

1) 12V Axial Fan: A 12V axial fan is connected to one of the relay modules used in this circuit and the GPIO pin corresponding to its supply is driven by the values from the DHT11 Temperature and Humidity sensor. For our setup, since the temperature was mostly sub-zero outside and the highest temperature achieved indoors was around 20°C, the threshold values from the sensor was kept at 18°C temperature and 60% humidity.

2) Active Buzzer and LED Lamp: An active buzzer is connected to one of the GPIO pins in the circuit. Whenever the raw value from the photocell goes below 190, the buzzer goes off to notify the user to manually turn on an external LED lamp, placed at an angle such that it falls directly on the plant and is reflected to the photocell which will make the value above 190 and the buzzer would turn off. This repeated monitoring is done every 5 minutes, which is an adequate buffer time and adequate for any plant, because it will not usually die off in just 5 minutes.

3) EZO Pump and Solenoidal Valve: An EZO pump and a two-way solenoidal valve are the two actuators associated with the ultrasonic water-level sensor. Whenever the water level goes below 5cm, the ultrasonic sensor sends a signal back to the Raspberry Pi which in turn sets the GPIO pin associated with the EZO pump as high and activates it. Water from the secondary container is poured in the primary container through the EZO pump until the sensor checks the water level again in 1 minute and sends a signal to stop it if the level is between 5 to 14cm. If the water level goes above 14cm, the sensor sends a signal back to the Raspberry Pi which in turn sets the GPIO pin associated with the solenoidal valve as high and activates it. The valve gets open and flushes out the excess water until the sensor checks the water level again in 1 minute and sends a signal to stop it if the level is between 5 to 14cm. This is

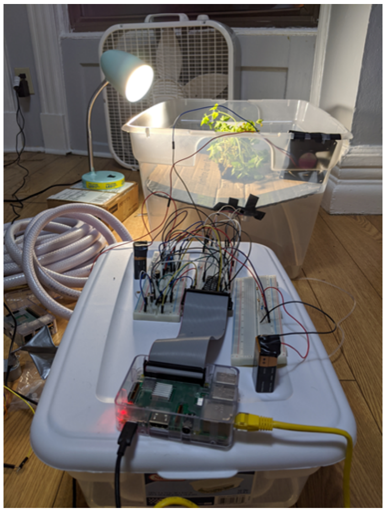

Fig. 4. Smart Home Garden Complete Setup

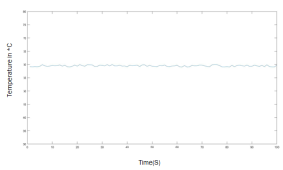

Fig. 5. Temperature sensor data

how the water level in the system is maintained.

V. Data analysis and prediction of optimal condition

Data acquired from the temperature and humidity sensor, light sensor and water level sensor is stored in a daily manner and those regions are detected and labelled where it crosses the optimal value meaning need of actuation. for a 24 hours time, data of each hour is analyzed for minimum variance implying reduced requirement of actuation(reduction in power dissipation). Mean of the parameters for this time frame where variance is lowest is chosen as optimum and stored with time-stamp(i.e, date). This way for a certain season we can achieve the optimal weather condition where the growth is best.
We proposed that, If this analysis is done on data of more than 6 months, the plot of the parameters concerned over time will display the weather variation which will match the real time weather detection up-to 80%. But since the entire set-up was made in an adversary weather situation, atmospheric conditions was needed to be strictly controlled, generating monotonous weather data. We have obtained sensor outputs as shown in figure 5, figure 6 and figure 7 depicting variation in weather condition, over one full day.

Smoothing available eight hours worth of data we get the optimal result as follows,

- **Optimal Temperature**: 21 degree C
- **Optimal Humidity**: 52%

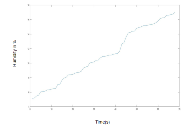

Fig. 6. Humidity sensor data

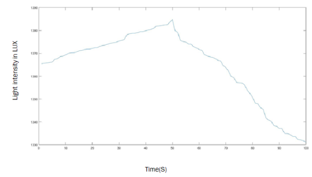

Fig. 7. ambient light sensor data

- **Optimal Light intensity**: 1250 Lux
- **Optimal Water level**: 12cm

VI. Limitation

Along the path of our project we have faced a few limitations while implementing the physical system. Primarily we proposed to use a sophisticated I2C enabled ambient light sensor TSL039. Though we were able to get the I2C driver, we were unable to access the Circuit-Python API for this sensor. Which limited our capability in light sensing and we used a photocell for light sensing. Though it can sense lack of required light intensity of 1250Lux, it is not precise enough.
Further LED bars with matched voltage and current rating as of the raspberry pi, was not readily available at our disposal. Thus we had to generate an alarm system for alerting the user.
For continuous monitoring, 12V dry-cell supply which was used for the experimental set-up was not enough for a self-sustained set-up. We would require a continuous supply for keeping the system alive.
For the EZO pump and solenoidal valve, although the voltage rating was matched, power rating was not matched for full scale operation due to limited availability of power sources.

VII. Possible future work

To make the system more robust and universal, sensors such as pH sensor, nutrient sensor and water temperature sensors can be incorporated in this system, which has not been included in this initial setup to keep the cost optimal. This is a system capable of being a part of fully automated smart home IoT grids, which can be controlled by smart phones or brand AIs like Alexa, Siri.

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