IoT And Automation Based Smart Urban Agriculture

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Abstract - *"**Plants**" are the most important part for human beings. Nowadays many of us are very passionate about gardening. My project is mainly focused on agriculture in Urban areas. Whether it is rooftop gardening or gardening in a greenhouse type area or something else. After the development of an Urban Agriculture area, there are always some people who take care of the whole system (e.g, watering, maintaining hydroponics etc.). I am using the IoT concept and automation to make this happen. I have built this system to replace human labor with the internet and technology. I have built a prototype of the system, it does not have all of our ideas which we can implement in real life but it will give a full blueprint of the production level system that we are dreaming of. We will discuss how we can replace humans with technology, how we can maintain our garden more efficiently with our technology, how we can bring the whole garden to your pocket and also my future plans for moving forward with this project.*

Key Words: IoT, Urban Agriculture, gardening, sensors, software, internet.

1. INTRODUCTION

In the era of urbanization, the demand for vegetables, fruits has increased insanely. In this time, the importance and needness for urban agriculture is increasing. To maintain urban agriculture(e.g, kitchen gardening, rooftop gardening, vertical farming etc.), being only dependent on human labor is problematic in many ways. My project is to replace the maximum human labor with technology. I have built a prototype that can decrease almost 80% of human effort. With the help of IoT, microcontrollers, programming we can make this happen. This project has two levels, one is based on IoT and another is based on Automation. These levels control the whole system. With the help of some input sensors and output electronic devices, the whole system works.

2. Urban Agriculture : What and Why

Urban Agriculture, urban gardening or urban farming is the practice of agriculturing in the city area. In this practice, we are processing, marketing food in our urban localities. It is also about animal husbandry, horticulture etc. Apart from urban areas, people are also developing this practice in outskirt areas of cities, called **pre-urban** areas. It has also an economic importance. It has opened a new door in agriculture where the agriculture is not only dependent on rural areas, the urban people also can get into it. The main idea behind practicing urban agriculture is to have easy access to locally grown food, understand the way of cultivation and gain basic knowledge of crop husbandry.

According to reports of FAO, by 2050, more than 6 billion people will be dwelling in urban areas, which is almost double the current population of 3.5 billion. In the case of India, the reports by the UN state of the world population 2007, by 2030, 40.76% of the country's population will reside in urban areas. By the above statistics, we can estimate the pressure on the rural production system to meet the increasing demand for fruits, vegetables in the urban market. To overcome the food crisis, we have to adopt urban agriculture. Urban agriculture is the savior to avoid this food crisis.

[Source: Chaitra Bhat and Amit Paschapur, "Urban Agriculture: The Saviour of Rapid Urbanization", Indian Farmer 7(01):01-09; January-2020]

3. Objective

- Minimum usage of humans in urban agriculture places.
- Continue monitoring the environment(e.g, temperature, humidity, soil moisture, plant height, intruder detection etc.).
- Automatic operations(e.g, watering, maintaining hydroponics etc) based on the values of various sensors.
- Scheduled operations based on input time intervals.

4. Technology

4.1 Hardware Components

- **Arduino Uno**

Fig-1: Arduino Uno

Arduino uno is a microcontroller which controls the input and output devices that are connected to it. In this system, it takes values from input sensors(e.g, soil moisture sensor, sonar sensor etc) and controls output devices(e.g, relay modules, buzzer etc.) on the basis of those values.

- **Esp8266**

Fig-2: ESP8266/NodeMCU

It is a wifi chip integrated microcontroller. It connects to the internet via wifi and sends values to the cloud. It is the main component of the IoT part of this project. It also works as an arduino and I will use it to control input and output devices.

- **Soil Moisture Sensor**

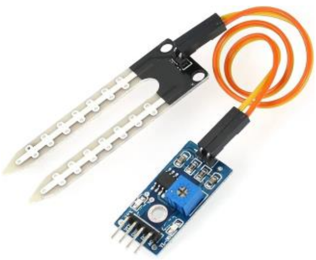


Fig-3: Soil Moisture Sensor

It detects and measures water in soil. It has 4 pins, VCC for positive power supply, GND for ground connection, AC for analog data output, DC for digital data output. I use an analog data output pin here to measure water in soil.

- **Ultrasonic Sensor(HC-SR04)**

Fig-4: Ultrasonic Sensor(HC-SR04)

There are 4 pins in this sensor, VCC for positive connection of power supply, GND for ground connection, TRIG is used to send ultrasonic sound waves, ECHO is used to receive the sound wave that was sent by TRIG. I will calculate the distance of an object on the basis of the time interval between outgoing sound wave and incoming sound wave. I will use this sensor to measure the height of plants and detect water level of hydroponics.

- **PIR Motion Sensor:**

Fig-5: PIR Motion Sensor

Human and animal body always reflects passive infrared rays. The sensor senses the ray and gives digital output. I will use it to detect movement of animals that could be harmful for the garden.

- **Relay Module**

Fig-6: Single Channel Relay Module

It has 6 pins. 3 pins for input, VCC, GND, IN for input signal. 3 pins for output, NC(Normally closed), COM(Common), NO(Normally Open). I will use it to turn on/off the water pump on the basis of a microcontroller signal.

- **DC Water Pump**

Fig-7: DC Water Pump (9V)

I will use it to water the plants.

- **DHT11 Sensor**

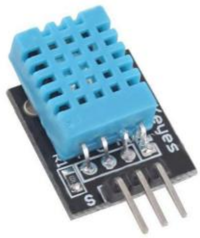


Fig-8: DHT11 Temperature and Humidity Sensor

It measures the temperature and humidity of a place where it is placed. I will use it to measure those of our agricultural area.

4.2 Programming Language, Libraries, IDE and Cloud Services

- **Blynk IoT 2.0**

Blynk

Fig-9: Blynk

I will use the Blynk IoT service and Android app for control and monitoring. I will monitor plant height, soil moisture, temperature, humidity etc. We will control water pumps.

- **Programming Language**

Fig-10: C++

I will use C++ to program Arduino and Esp8266.

- **Libraries**

1. DHT.h
2. ESP8266WiFi.h
3. BlynkSimpleEsp8266.h

- **IDE**

Arduino IDE

Fig-11: Arduino IDE

I will use Arduino IDE to code Arduino.

4.3 Description

The system is divided into two levels. One is IoT and another is Automation.

4.3.1 Level 1

4.3.1.1 IoT Plant Watering

- How It Works

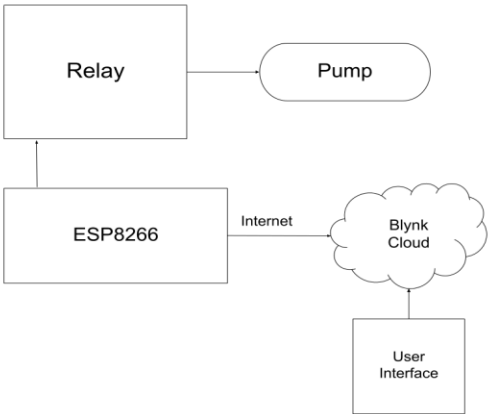
It works on the IoT concept. In this part, we control the water pump through our mobile application. We don't need to be physically present to water our plants. We just need to install the Blynk app to our android device, login with our username and password. There is a switch, by turning it on the switch the pump will turn on and start watering the plant. By turning the switch off, the pump will turn off and stop watering the plant.

- Real World Implementation

In vertical farming, rooftop gardening etc places, we will use a **water spray pump** instead of normal water pump in which by spraying water on high pressure, a single IoT system can give water to more than one plant. **Not only water, we can also give liquid solutions, pesticides to plants by this system.**

This is a large field but we will use this technology with IoT in urban agricultural places. The power of the water spray pump will vary on the basis of how large the place is.

- Block Diagram



- Working Methodology

When we switch on the Blynk app, the data goes to Blynk cloud, then the code in nodemcu, fetches the data from the Blynk API and sends a digital signal to the relay module. On the basis of the signal, the pump turns on/off. I have used *"BlynkSimpleEsp8266.h"*, the library, to connect to ESP8266 with Blynk. Blynk auth token, wifi ssid, password has been coded in nodemcu.

- Scheduling

By using the "Automation" feature of Blynk, we can set a limited time to conduct this operation. For example, we can set 5 hours as a time interval. That means, every 5 hours, Blynk sends data to nodemcu to turn on the pump for a limited time which is initialized in the code of nodemcu. You do not need to remember to water your plants.

- Precaution

The water tank from where the pump will supply the water should be always full. Now in the market, there are many devices that automatically fill the tank when it is empty. We can install this in our tanks, then it will never be empty.

4.3.1.2 IoT Plant Height Monitoring

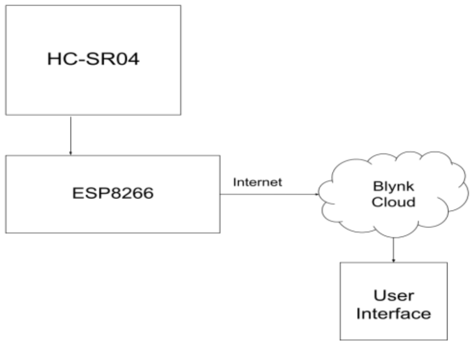
- How it works

Place a sonar sensor above a plant. When the plant slowly increases, it will go closer to the sensor. Sensor is always looking for the distance of the object in front of it. So, the sensor can track the changes of height in the plant on the basis of the distance. It always sends data to the Blynk cloud.

- Setup

Let's place a sonar above a plant and the distance is 5 inches. Make it the initial value in the Blynk app, so, in the app, the data will show 0. Now, check the minimum distance of the sonar sensor. Make that minimum distance as maximum distance in the Blynk app. Let's assume the minimum distance is 10 inches. Now, the Blynk app is showing distances between 5 inches to 10 inches. So the growth of the plant is more clearly visible.

- Block Diagram



4.3.1.3 IoT Temperature and Humidity Monitoring

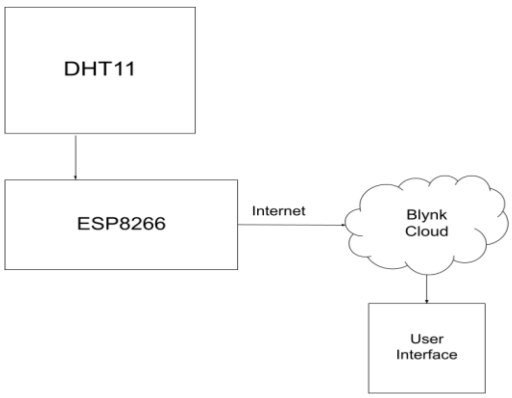
- How it works

I have used DHT11 to measure the temperature and humidity of the place.

- Working Methodology

DHT11 has 3 pins, VCC, GND, Data. I have connected VCC to a 5V pin of nodemcu and GND to a ground pin of nodemcu and Data to a digital GPIO. *"DHT11.h"* library has been used to take temperature and humidity values from the sensor. Both come as analog values. It gives 0-50 degree celsius temperature value with a 2-degree accuracy and humidity range is 20% to 80% with 5% accuracy. It sends data to the Blynk cloud and we can get the data from our Blynk app.

- Block Diagram



4.3.2 Level 2

This level is quite big. At this level, I have used various sensors, programs to automate each and every operation.

4.3.2.1 Automatic watering based on Soil Moisture

- How it works

A soil moisture sensor is placed in soil. By measuring water quantity present in that soil, the system will turn on/off the water pump. The soil moisture value will be sent to the Blynk cloud, that is how we can monitor whether our plants are getting water or not.

- Working Methodology

I have set two values in arduino code. One is the minimum moisture value and another is maximum moisture value. When the moisture of soil decreases below the minimum value, the water pump will start watering. When the moisture value goes above the maximum value, the water pump will stop watering. I have connected the AC pin of the soil moisture sensor with both arduino uno and nodemcu, so that the value is not only utilized by arduino but also sends the value to Blynk via nodemcu.

We know there is only one analog pin in nodemcu and we will need more than one soil moisture sensor. In that case, we can use a 12-channel analog multiplexer module to increase analog pins in nodemcu.

- Real World Implementation

Let's assume, we have a 5ft long, 4 ft wide and 5 inches depth tray where we have planted more than 10 saplings. Now, we need to set this system. We will make 5 columns, each column is 1 ft long. We will set one sensor per column. Set a 12V DC water spray motor in front of the tray. Now, with 5 sensors, we can measure the moisture of a long place and supply water to more than 10 plants. We can also use this idea in large agricultural land. Then we will need more powerful pumps to cover the whole area. We can also monitor the moisture from anywhere via the internet.

4.3.2.2 Automatic Intruder Detection

- How it works

The PIR sensor detects human and animal movement. When any animal tries to enter the garden, the alarm will ring and the animal will run away from the garden. If it comes into the garden anyway, still when it moves, the alarm will ring and the animal will have to go out from there.

- Working Methodology

The PIR sensor has 3 pins, VCC, GND, Out. Set VCC to positive 5V, GND to ground and OUT to digital GPIO of nodemcu. A buzzer is connected to another digital GPIO pin and GND. When the sensor detects something, the buzzer starts ringing for 30 seconds.

4.3.2.3 Advanced Hydroponics System

- What is "Hydroponics"?

Hydroponics is the cultivation of plants without using soil. Hydroponic flowers, herbs, and vegetables are planted in inert growing media and supplied with nutrient-rich solutions, oxygen, and water. This system fosters rapid growth, stronger yields, and superior quality. When a plant is grown in soil, its roots are perpetually searching for the necessary nutrition to support the plant. If a plant's root system is exposed directly to water and nutrition, the plant does not have to exert any energy in sustaining itself. The energy the roots would have expended acquiring food and water can be redirected into the plant's maturation. As a result, leaf growth flourishes as does the blooming of fruits and flowers.

- How The Machine Works

There is a tank of nutrient solution. A water pump is connected to it, so when the water pump turns on, it supplies a nutrient solution, not water. There is a long aquarium where all the plants are placed. The plants are above the aquarium but their roots are sinked in the nutrient solution. When those plants completely take all the solution, the water pump will automatically supply the solution from the tank. The height of the solution level is always sent to the Blynk cloud.

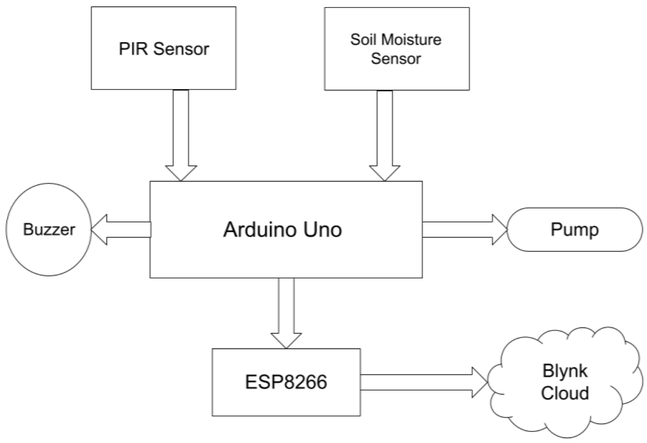
- Working Methodology

I have placed a sonar sensor on the plane where the plants are also placed, the upper plane of the aquarium. Now, the sensor can easily measure the water level. I have set a minimum distance and a maximum distance in nodemcu board. When the water level goes below the minimum distance, the water pump will start supplying the nutrient solution. After reaching the maximum level, the water pump will stop supplying solution.

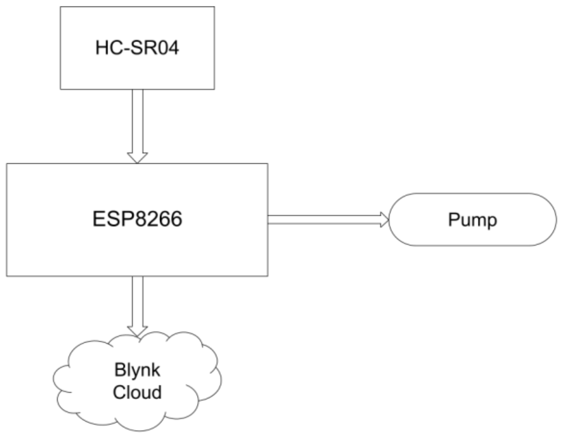
- Real World Implementation

We can easily implement this. We can add some sensors but without any changes, it is still ready for execution.

4.3.3 Level 2 Block Diagram



4.3.4 Advanced Hydroponics Block Diagram



4.4 Connect Level 1 to Level 2

- What If Any Sensor Fails

Suppose, a soil moisture sensor got damaged, then how plants get water? In that case, we can combine Level 1 with Level 2. We will connect every water pump with both an IoT system and Automation system. So, if any sensor from the automation system fails, we still supply water through our mobile app. We can see the moisture level in our app, so, when we see that the moisture is below minimum moisture value for some time, we will understand that something wrong has happened to our automation system, then we will supply water through the Blynk app.

It is also applicable for the **Advanced Hydroponics System.** When we see that the solution level is below minimum distance, we will supply a solution with our Blynk app.

We can add a notification system with it. When the water level of hydroponics or moisture level of soil is below the minimum level for more than a certain time then the system automatically sends a notification to the user. So the user get an alert and does it over the app.

4.5 Future Plans

- I will add a PH sensor to understand what fertilizer and how much fertilizer should be applied in soil.
- I will add a NPK sensor to measure nitrogen, potassium and calcium in soil. That will help in understanding what fertilizer and how much fertilizer should be applied.
- A system is needed to take the stale solution out from the aquarium of hydroponics. At a certain time interval, stale solution will be taken out and fresh solution will be supplied.
- I will design my own backend server and hardware setup so that a user can add more hydroponics, more plants to the system just by doing some simple steps without knowing any technical knowledge(e.g, circuits, programs etc.) about the system. It will make the system more user-friendly.
- I will use machine learning to measure the height and health of plants. By implementing some cameras with machine learning technology in agricultural areas, we will be able to take day by day notes about the health of plants. It will make this system more efficient.

5. Conclusion

This is an advanced IoT system that has the ability to replace most of human work in the Urban Agriculture area. It will also decrease the cost of maintenance. This is to continuously keep an eye on the whole environment. We have seen how much we need urban agriculture to avoid the future food crisis. If I get any chance, I will definitely implement this system on a rooftop garden or something else and will observe the changes.

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BIOGRAPHIES

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I am a final year student. I am pursuing Bachelor's in Science in Computer Science from Siliguri College. I am very passionate about coding, IoT and embedded systems. I am a Full Stack Web Developer that will help me to build my own IoT platform.