Automation and Optimization in Vertical farming using IoT and control system

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Article Information	ABSTRACT
	The pandemic has had an impact on agriculture output yield. The unpredictability of the environment, such as warm winters and chilly summers, has had a significant impact on crop production percentages in India, forcing many farmers to refrain from crop planting. In order to solve this, we developed an autonomous agricultural solution. To maximize yield, our device can monitor and manage environmental conditions. The goals of this project are to successfully cultivate healthy plant life without much direct human intervention. To produce the most output in the smallest amount of space.

1. INTRODUCTION

We have developed an autonomous agriculture solution. Our device is capable of monitoring and controlling the environmental variables to optimize production. We are using Arduino IDE, EasyEDA, Debian (Linux distro), Pycharm, VScode software with possibly recursion, backtracking or greedy Algorithms and nrf240L1, atmega328p, Raspberry Pi and various sensors as hardware. The objectives of this work are to successfully grow healthy plant life without much direct interference from the user. The system consists of three main parts:

1. Nodes: These are responsible for the data fetching from the environment and controlling the various appliances like irrigation and air-flow system
2. Gateway: Brain of the project which will run PID code, control the Nodes and Upload the data to the database.
3. User Interface:-
● Front-end: It will give user insight and control of environmental variables while offering a great user experience.
● Back-end: It will host the front end while also parsing the data provided by the user on the front end to the gateway and vice versa.

The project's outcome is the design/implementation of two working nodes and a gateway that will be responsible for controlling the environmental variables around the plants as per-user configuration. This prototype has possible use in vertical and indoor farming and has a cost of roughly around 13000 INR.

We have learned the following skills during work.

1. Teamwork
2. Communication skills
3. Project Management system.

We have acquired technical expertise on

1. Analogue and digital circuits
2. C, python, HTML, CSS, ReactJS, NodeJS
3. Raspberry Pi
4. Linux
5. Databases
6. Control System,
7. Engineering Drawing
8. BASH
9. Heroku
10. Firebase.

2. LITERATURE SURVEY

The existing method of going for vertical farming is complicated, expensive and has some limitations in it. The challenge of making vertical farming grow is crucial. When we run out of fresh fertile soil or space to plant the plants, vertical farming will play a crucial part in the agriculture sector. In this section, we briefly addressed some of the current research publications related to our study. For details on related research, and publications refer the Table 1.

Title	Conclusions	Limitations
"Greenhouse Management Using Embedded System" by Thenmozhi, S., Sudharsan R, Dhivya M.M., and Nirmala Kumari K	A control system is created to monitor the greenhouse environment parameter properly. Designed to record all the values and parameters	The cost of solar panels was very expensive The use of ZigBee for manual control is quite expensive while cheaper alternatives are available.
"Solar Powered Automatic Drip Irrigation System (SPADIS) using Wireless Sensor Network Technology" by Shah, AFM Shahen, and M. Shariful Islam	Was Developed for irrigating farmland by measuring soil moisture. Discourages weed saves water and time, and can also provide statistical data.	The android app used to display data works only via Bluetooth for a short-range
M P, Pavithra. (2018). **VERTICAL FARMING: A CONCEPT.**	A brief study on the concept of vertical farming, its benefits and limitations.	No active case studies on the implantation of vertical farming
VERTICAL FARMING: A REVOLUTION TO SUSTAINABLE AGRICULTURE Carly Sills, cps41@pitt.edu, Mandala 2pm, Isaac Serbin, iss33@pitt.edu, Mandala 2pm	This paper discusses in length about the impact of vertical farming on many levels such as environmental, social, etc.	While many solutions were provided none were implanted in this paper.
A review of vertical farming technology: a guide for implementation of building-integrated agriculture in cities	This paper discusses farming methods, food production and controlled environment agriculture	No real applications are presented
Park, Dae-Heon & Kang, Beom-Jin & Cho, Kyung-Ryong & Shin, Chang-Sun & Cho, Sung-Eon & Park, Jang-Woo & Yang, Won-Mo. (2011). **"A Study on Greenhouse Automatic Control System Based on Wireless Sensor Network. Wireless Personal Communications"**	The system proposed in this paper collects the temperature of leaves and humidity on leaves of the crop. As well as greenhouse environmental information such as temperature, humid33ity, etc.	This system has good features, but it is more expensive due to its components.

Research on Control System of Intelligent Greenhouse of IoT Based on Zigbee	This system is a greenhouse system implemented with the IoT based ZigBee network. It is efficient for communication between nodes	The only downside to this project is the cost of the ZigBee network, as these modules work in short-range so many modules would be required to make a network
"A Research on Hydroponics – Growing Plants without Soil" by Sourabh Ramakrishna	Every system has limitations, but with additional precautions, this method can reach a two-fold increase in growth as well as yield when compared to crops grown in soil.	This system requires ongoing maintenance and is vulnerable to water illnesses and power outages. It is an extremely costly system.
"Robust Smart Irrigation System using Hydroponic Farming based on Data Science and IoT" by Punya Prabha V1, Sarala S M2, Sharmila Suttur C3	With the help of the internet of things and data analysis this system works on water management, perfect amount of nutritious solution. this system is built for people who have less space and time so all the work is done by machine learning algorithms which take photos of plants and analysis them	

Table 1.

3. METHODOLOGY

The first phase in the process is to conduct vertical farming research; vertical farming includes several sub-types: Hydroponics, Aeroponics, and Aquaponics. Aeroponics involves spraying nutrient-rich water directly into the roots of plants.

This is a complicated process which requires complete and precise control over the surroundings, this will be hard to replicate on a small scale and will require expensive equipment.

In aquaponics the plants are paired with a specific variety of fish which produce waste which is excellent for the growth of plants, this can't be replicated since even the smallest compatibility issue can cause failure and endangerment of a living creature is not suitable.

Hydroponics fulfills the project requirement as most attributes of the hydroponics system can be controlled and monitored.

The selection of appropriate yield is necessary to use the project at its fullest potential; the leafy vegetables are selected due to their fast growth rate and large leaf surface area aid in exponential growth rate.

The surrounding attributes are to be measured with the help of various sensors and various electronic output devices will be used to control environmental factors. The main environmental variables that affect plant growth in hydroponics are air temperature, air humidity, CO2 concentration, Light intensity, water temperature, water pH, and water TDS (water TDS can be enhanced using a nutrition solution),(water

TDS can be enhanced using a nutrition solution), and the needed TDS range for leafy vegetables is roughly 800ppm to 1200ppm.
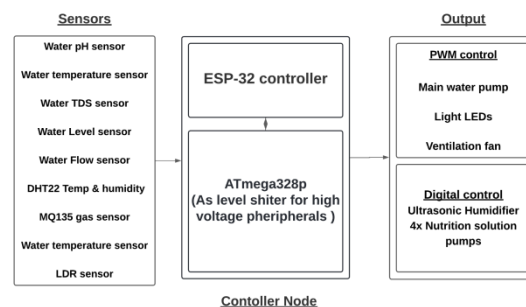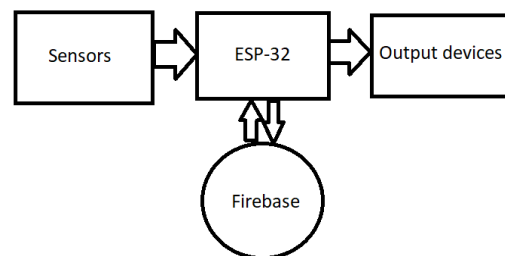
4. RESULTS AND DISCUSSION

In this section, it is explained the results of the research and at the same time is given a comprehensive discussion. We discussed in depth the research completed on the plant growth cycle, as well

as how plants should grow and how data from sensors is read and how it influences the system.

4.1 SEED GROWTH AND NUTRITION

We have planted our seedlings in an agriculture sponge. This sponge is helpful for the germination and growth of the seeds in the early stages of growth. During the first two weeks of seed growth, the seed is allowed to grow by using only water, after which it is safe for us to grow seeds using nutrition solution "A & B" at half or quarter strength of the normally required concentration.

In the table below, the amount of solution necessary is clearly described.

	For Circulating System	
mL/1 Liter	Leafy A	Leafy B
Cutting & Seedlings	1ml	1ml
General Purpose	4ml	4ml

Table 4.1 Nutrition Solution Guidelines

It is recommended that we keep the PPM reading of our nutrition tank within 1000 – 1200 ppm and pH Level within 5.5 to 6.5.

4.2 SEED GROWTH CYCLE FOR SPINACH

Spinach is one of the most grown plants in a hydroponic system. In a hydroponic system, spinach develops quickly because it receives nourishment straight from the nutrition solution. The amount of water required is also comparatively less when compared to soil farming.
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4.2.1 SEEDING

It is important that we soak the seeds of spinach under warm water for an hour. The purpose is to soften the seed's outer layer.
Each sponge will contain one seed only. After planting the seeds, we need to keep all the planted seeds in a tray and keep it under shade. We can cover the tray with plastic so that the seed grows faster. The seed will generally germinate after 2-3 days, or when at least 2 or 3 leaves appear, we can move the tray to the source of sunlight. Sunlight can come in two forms: natural and artificial.

4.2.2 LIGHTING REQUIREMENT

Spinach needs 12 hours of light every day on average. During the peak of summer, it is important to not let the plants be exposed to direct sunlight but under the protection of a partial shade. Putting a blue light improves chlorophyll production, while red and yellow light are good for spinach production. Using dual spectrum light would be perfect.
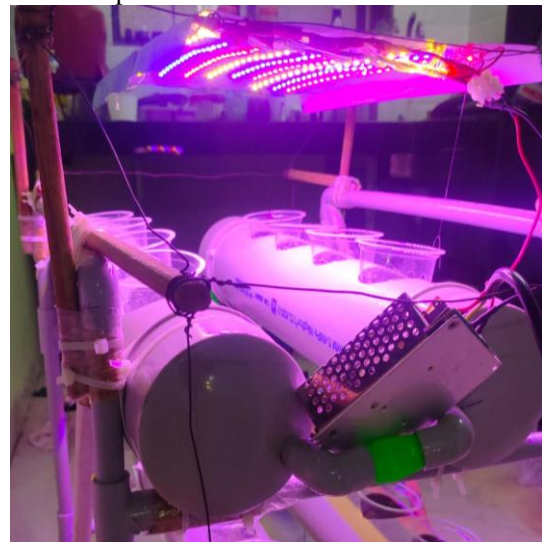
4.2.3 PREPARATION OF MEDIA

In this stage we prepare our plants to be stored in our hydroponic system, we are storing our plants in plastic cups which have holes in them for sufficient flow of water.

4.2.4 NUTRIENTS REQUIRED

For the first week of the growth of the plant no extra nutrients are required at this stage. After which the plants are supplied by $1/4^{th}$ the strength of the nutrition solution. After two weeks we increase the strength of the nutrition solution to normal strength.

4.2.5 MAINTENANCE AND CARE

Some following points were considered during the growth of the plant: -
- Regular watering but don't make a puddle.
- The plant should never face dryness.
- Plant weeding should be done on a regular basis.
- Weeding was done to prevent the arrival of pests and diseases.
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4.3 SENSOR TESTING DATA

Many sensors were used in this project such as DHT11, Water Flow Sensor, TDS Sensor, pH Level Sensor and Water Level Sensor. Each sensor used has its own purpose in the project. The sensors provide real-time or periodic data on what is happening in the hydroponic system. Data such as temperature, humidity, ppm values and pH level of the water solution.

4.4 WEB FRAMEWORK

We are collecting the data from sensors and sending it to a server which will further send it to a database based on a cloud service. We have collected data from our database to be rendered or visualized on our website by utilizing this capability.. The website will help in visualizing data and comparing it with past values or finding out patterns based on past records.

The website can also show an alert if something is detected to be not working. The database used here is MongoDB, and Firebase is also a good alternative that can be used as a database.

We are using an MQTT Server to patch the data from sensors to the database. The data is retrieved from the database via an API, which is then utilized to present graphs and numerical figures for various agricultural setup settings.

5. CONCLUSION

The outcome of the project is the design/implementation of a control node that will be responsible for controlling the environmental variables around the plants as per-user configuration. This prototype has possible use in vertical and indoor farming and has a cost of roughly around 13000 INR.

6. REFERENCES

All references should be to the majority relevant along with current sources. References are written in **IEEE style**. Please utilize a consistent format for references–notice cases are given here:

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