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IoT Monitoring in Hydroponics for Improved Crop Health

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Abstract

Hydroponic irrigation is one of the alternative sources for growing plants in soilless medium. This requires less water, natural nutrients and less space which will increase the yield per unit area. Hydroponic system is also a suitable alternative of traditional method of growing crops as it can meet food demand to an extent. The proposed system aims to provides continuous monitoring of pH, water level, air temperature, and humidity. Moreover, regulated irrigation of water and nutrient solutions by using sensor mechanisms. Information is processed, controlled, implemented, and exchanged internally via the Internet collected by the sensors and the use of cloud-based technology as the backend. In this project, a fully automated system for hydroponic plant growth monitoring system is proposed. The key utilization behind this automated system is to develop any suitable plant, indoors, and without humans Intervention.

Introduction

Hydroponics makes it possible to harvest several crops throughout the year, without chaotic discharges of either pesticides or fertilizers to the environment, and using less land and water than traditional open-field agriculture. It requires some skills to operate this system. The main challenge is low literacy rate among farmers, which is low and in order to prepare them, we need to guide maximum number of farmers so that those farmers could guide and teach another one. The climate change, labour unavailability etc. possess major limitations against the growth of the present-day agriculture.

Hydroponic systems, a popular technique of highly resource and space efficient form of cultivation, already contribute extensively to global food production. Setting up a hydroponic farm is much more expensive than traditional farming. The lack of education and awareness among farmers about all of these concerns and technical improvements is a major problem. Technical understanding, to the extent of micro-managing temperature and humidity, is required. A single blip in the ambient temperature might result in significant crop losses. Even though the growth of hydroponics in agriculture is rising every year, it seems there is still a large population of farmers who are not much aware about hydroponic systems.

Agriculture is the backbone of economy in various developing countries government supports the farmers to increase the income by adopting technological advancements and establish smart farming instead of traditional methods. Hydroponics requires deep skills and practical knowledge to grow crops. A large-scale application set up requires technical knowledge. Plants will die out more quickly without proper care and adequate knowledge. Hydroponics saves between 70-90% more water than soil, as water is recirculated and reused. There are additional benefits: Crops may yield up to three or four times that of traditional gardening. In addition, as there are no soil-borne pests, hydroponics reduces the need for pesticides. It also uses 60% less fertilizer than traditional methods.

Commercial hydroponic systems are automatically operated and expected to reduce labour and several traditional agricultural practices can be eliminated, such as weeding, spraying, watering and tilling. Higher yields can be obtained since the number of plants per unit is higher compared to conventional agriculture. Clean water is essential for the production of high-quality horticultural products. Water quality is an important thing in any hydroponic system. Plants which are grown in clean water grow faster, healthier and with less problems. Poor quality water can lead to a number of plant growth problems such as stunted growth, mineral toxicity, elemental deficiency symptoms, build-up of unwanted elements in plant tissue, bacterial contamination etc.

The health condition of the crops is continuously monitored with the help of data that are collected by the different sensors such as PH , Temperature, Humidity etc . Thus, this hydroponic system can be adopted in any environmental conditions and it is a fully automated setup that can be operated through IOT.

IoT technology allows for the integration of various sensors that monitor crucial factors such as temperature, humidity, pH levels, nutrient levels, and light intensity. These sensors provide real-time data, enabling growers to make informed decisions and optimize conditions for plant growth. IoT integration enables automated control of hydroponic systems. By using IoT devices, growers can remotely monitor and adjust environmental conditions, nutrient delivery, and lighting schedules, ensuring optimal growth conditions without the need for constant manual intervention. IoT devices collect and transmit data, which can be analysed to gain valuable insights. Growers can utilize this data to identify patterns, optimize resource allocation, improve crop management, and make data-driven decisions to enhance overall system efficiency.

The objective is to atomize the crop monitoring during the growth process using the network of sensors. The goal is to track and supervise the plant growth safe. Indoor farming/gardening is the future for agriculture, where we don't need vast lands for agriculture. It will allow one farmer to work more than one job and cultivate more than one farm simultaneously.

Design framework for hydroponic automation:

Environmental Control:

- Temperature and Humidity: Install temperature and humidity sensors to monitor and maintain optimal levels for plant growth.
- Ventilation: Use fans or automated vents to regulate airflow and prevent excessive heat buildup.
- CO2 Levels: Incorporate a CO2 sensor and controller to maintain the ideal CO2 concentration for photosynthesis.
- Light Control: Utilize timers or light sensors to automate the lighting schedule and provide consistent light intensity.

Nutrient Delivery:

- pH and EC Monitoring: Integrate pH and EC (electrical conductivity) sensors to monitor nutrient solution parameters.
- Nutrient Solution Mixing: Automate the mixing of nutrient solutions by incorporating pumps and valves controlled by timers or sensors.
- pH and EC Adjustment: Use pH controllers and dosing pumps to automatically adjust pH and nutrient concentrations in the solution.
- Irrigation System: Implement a drip irrigation system or nutrient film technique (NFT) to deliver the nutrient solution to the plants.

Monitoring and Data Collection:

- Sensor Integration: Connect various sensors (e.g., temperature, humidity, pH, EC) to a central monitoring system.
- Data Logging: Collect and store sensor data to track environmental conditions, nutrient levels, and other parameters over time.
- Remote Monitoring: Enable remote access to the monitoring system for real-time data visualization and control.

Control and Automation:

- Microcontroller/PLC: Utilize a microcontroller or programmable logic controller (PLC) as the central control unit for the automation system.
- Actuators: Connect actuators such as pumps, valves, fans, and lights to the control unit for automated control based on sensor inputs.
- Automation Logic: Develop a control algorithm that considers sensor readings and pre-set thresholds to trigger specific actions for environmental and nutrient control.

Alert Systems and Notifications:

- Alarm and Notification Setup: Implement an alert system to notify growers in case of critical conditions (e.g., temperature or pH outside safe ranges).
- Mobile or Email Notifications: Configure the system to send notifications or alarms via mobile apps or emails for immediate attention.

Integration with IoT:

- IoT Connectivity: Connect the automation system to an IoT platform for remote monitoring, control, and data analysis.
- Cloud Storage and Analytics: Store sensor data in the cloud and leverage data analytics tools to gain insights and optimize system performance.

Proposed Research-

Hydroponic water requires two types of testing – PH and EC. Both types of testing are most accurately measured with meters. To do so, power the meter on, stick the probes into the water, and read the display on the meter. PH test strips can also be used to test hydroponic water also. Simply dip the strip into the water for a couple of seconds and pull it back out. The results will appear after approximately 10 seconds. If the pH level is high, all we need to do is add something containing alkaline, such as baking powder, to lower it. On the other hand, when pH levels in the water test low, adding citrus raises it up. Lemon juice or white vinegar are a couple of the most common household items used for this purpose. When testing pH levels in the water, if an extreme unbalance is noted, changing the water right away is always the best course of action. Avoid using chemical-based cleaners or soap and stick with elbow grease and/or plant-friendly cleaning solutions. The water temperature in any hydroponic system should be monitored and maintained between 65F and 80F. Overwatering can and does occur in hydroponics. The water is mixed with the nutrient's inappropriate proportions according to selected crop. The pH of nutrient-enriched water must be taken care of. Readings are taken from the water and will track the effective pH. Water Level Sensor to get to know the level of nutrient enriched water this sensor is used. The level of water in the hydroponic system can be noticed by using this sensor. The roots of the plant are totally immersed into the water which contains the specific Growth nutrient. An air pump with helps oxygenate the water and allow the roots to breathe. The chemical composition of the nutrient solution depends on specific crop and plant development stage. depending on their growth stage, plants require different formulations; thus, during the vegetative state, the plant grows foliage until ready to flower or root ripening, at which point a nutrient solution rich in phosphorous is required by the plant to build strong roots. Finally, during fruit ripening, the plant requires nutrient solutions low in N and high in K concentrations.

The average home hydroponics system needs its water fully changed every two to three weeks like clockwork. In between full water changes, feel free to top off your water levels by adding small amounts of water every so often. The harmful bacteria from the algae may produce disease and infect the plants.

Various components and sensors connected to an IoT platform.

Sensors: In hydroponic system, sensors such as temperature sensors, humidity sensors, pH sensors, EC sensors, light sensors, and CO2 sensors placed strategically throughout the growing area. These sensors collect real-time data on environmental conditions and nutrient parameters.

Microcontroller/PLC: A microcontroller or a programmable logic controller (PLC) acts as the central control unit. It receives data from the sensors and processes it to make decisions and trigger specific actions.

IoT Gateway: The microcontroller/PLC is connected to an IoT gateway, which serves as the bridge between the local automation system and the internet. It enables communication between the hydroponic system and the IoT platform.

IoT Platform: The IoT platform receives the data from the hydroponic system through the gateway and stores it in a cloud-based database. This platform provides various functionalities like data storage, visualization, analytics, and remote access.

Remote Monitoring and Control: By accessing the IoT platform through a web portal or mobile application, growers can remotely monitor the environmental conditions and nutrient parameters in real-time. The farmer/user can view sensor readings, check historical data, and receive notifications or alerts for any abnormal conditions.

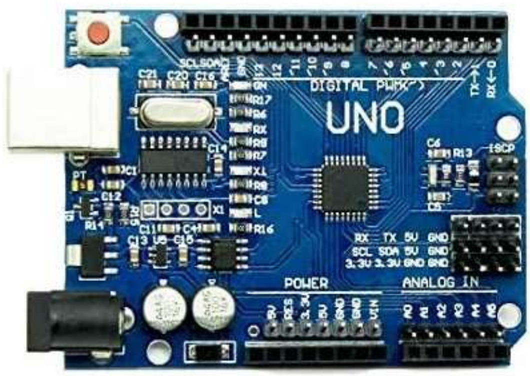
Automation and Actuation: Based on the data received from the sensors, the microcontroller/PLC can automate various processes. For example, it can control the operation of pumps for nutrient solution circulation, adjust pH and EC levels, regulate lighting schedules, or control ventilation fans.

Data Analytics: The data collected by the IoT platform can be analyzed to gain insights and optimize the hydroponic system's performance. Growers can identify patterns, track trends, and make data-driven decisions to improve crop growth and resource utilization.

WORKING-

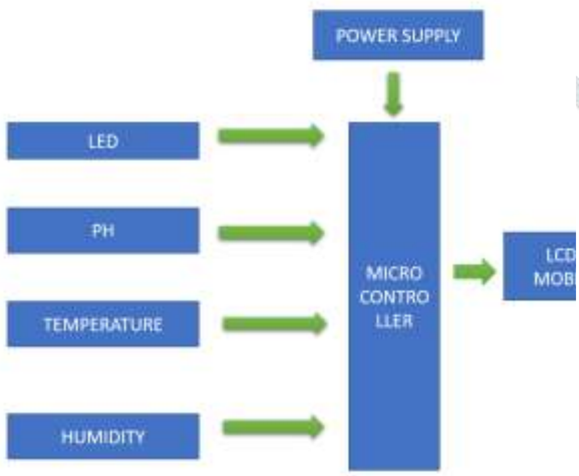
The system makes use of sensors to monitor temperature, moisture and water level in the grow chamber. The system monitors these parameters and operates the fans to maintain required temperature and moisture in the chamber. The system then uses the water sensors to check level of water in the system, the pump motors pump water into system or remove excess water from the system as and when needed. The artificial sunlight is switched on and off automatically to maintain proper temperature and get desired light for plant growth.

The system uses two Arduino microcontrollers acting as nodes. Nodes take the data from the different sensors and send the data to a third Arduino acting as a gateway in the IoT network. NRF24L01+ radios are used for the communication between the nodes and a gateway. The gateway is connected to the Raspberry Pi running a local server which makes the data available on the web interface and mobile application. The LED's provide light to the growing plant.



The state of the system is monitored by using various sensors. An air pump is used to infuse the water with oxygen for the plant to absorb through its roots. The system contains four sensors: an electrical conductivity probe, a pH sensor, a water temperature sensor, and an air temperature/humidity sensor. The electrical conductivity probe allows us to estimate an amount of salts or nutrients in the water. The pH probe must be calibrated using calibration liquids . Measuring the pH allows us to properly adjust the pH of the water before putting the young plant into the system. The EC and pH probes are connected to a transmitter to convert the information received by the sensors into pH and EC values. Distilled water was used to have base pH value close to 7 and adjusted to be between 5.6 pH – 6 pH after adding nutrients. Measuring the pH of the water at consistent temperatures is vital since the pH is dependent on temperature.

The system uses Arduinos which are programmed using the Arduino IDE. The software is responsible for operating the sensors and lights. The system was configured as a sensor network in Internet of Things by using an open source API called AjusSensors . This enables the creation of nodes, gateway, and communication between them. The system uses a Raspberry Pi which is running a local server to enable remote monitoring and control of the system. A small script runs on Raspberry Pi to automatically monitor the state of the server and restarts it if necessary.



Type of Crops	Name of Crops
VEGETABLES	TOMATO, CHILLI, BEET, CAULIFLOWER, MELONS, CUCUMBER, CABBAGE
FRUIT	STRAWBERRY
CONDIMENTS	MINT, PARSLEY
FLOWER	MARIGOLD
MEDICINAL	ALOE VERA
FODDER	BARLEY, SORGHUM
LEAFY	LETTUCE,SPINACH,Mustard,Lettuce,Coriander

Hydroponic kit cost (cost in India)- area = 4.5 sq. feet RS 2500 (1 PIECE).

Results and analysis-

Data analysis was done using the logs that were kept by the Ajus software. Each log is updated constantly and demonstrates the values that were reached each day. The air temperature log shows the progression of temperature from 24°C to 20°C as the day turns into night. The amount of time the lights were ON and at what time they switched state (from ON to OFF or from OFF to ON). This is needed to make sure that the plant is getting the optimal amount of lighting. The water log keeps track of the water temperature that the plant is sitting in. The pH log shows the change in pH levels over time. As the plant consumes more and more nutrients from the water the pH value increases. This is because of the acidic nature of the nutrients. After the data analysis the result will send as a message to the farmers mobile.

Conclusion

The hydroponic system proves to be using less amount of water, faster growth of plant, more productive and healthy plants growing system. The proposed system enables an easy method of farming and growing plants that ensures perfect balance and better yield. With hydroponic farming method, the arable space problem will be solved in the future. The primary focus was on high productivity and low land and water use, controlled-environment agriculture. The hydroponic farming will reduce pests and weed production on alarming levels. In this paper we are trying to monitor of systems and the automation of nutrient supply. Moreover, the system automatically sends an alert message to the concerned farmers mobile. It helps in achieving higher productivity, enhancing the quality of horticultural produce and very helpful for homemade garden or tersest gardening purpose.

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