Hydroponic Automation System

Saptharishee M
SCOPE
VIT Chennai
Chennai India
saptharisheemuthu@gmail.com
+91 7708709518

Vishakhaa S
SCOPE
VIT Chennai
Chennai India
vishakhaasridhar@gmail.com
+91 97908 88400

Yashwanth Sarathi
SCOPE
VIT Chennai
Chennai India
yeshwanthsarathy.sp2020@vitstudent.ac.in
+91 99627 89434

Abstract

Human population density rises dramatically in densely populated metropolitan areas, reducing accessible farmland. As a result, a landless planting method is required to offer food for civilization. Hydroponics is one of the agricultural technologies that uses water as a nutrition medium. Hydroponics is proved to use 80-90% less water than traditional methods [5] where soil acts as a medium between us and the plant. Hydroponic farming is usually done manually by monitoring nutrition parameters like as acidity or basicity (pH), total dissolved solids (TDS), Humidity, Ambient temperature and nutrient solution temperature. In this study, we present a system that uses IOT where a couple of sensors and internet help us record the data in the hydroponic system and the machine learning model helps us automate the process of monitoring the system The proposed system uses data from thinkspeaks cloud in csv format and performs a ensemble learning using supervised machine learning to stack and uses Support Vector Classifier as meta estimator. The system works with 97.66% accuracy

Keywords: population density, Hydroponics, landless planting, IOT, thinkspeaks, ensemble learning, Support Vector Classifier.

1. Introduction

Collecting data of a physical object based on a specific already accepted standards is called measurements. Measurements include mass, pressure, temperature, humidity and so on. The measurements are done using sensors which converts physical measure to electrical signal read by an instrument. Integrating the sensor with computer thorough internet opens gateway for various applications including data analytics, modelling, predictive analysis and other aspects. The controlling system will help in observing an object parameter . A system works to measure object parameters, store and display the measured data on a regular time interval. The system may identify anomalies and indicate the user if the observed data is over a limit. Traditional controlling system stores, displays and works only on a small local area.

The advancement of internet enables communication in several form that include person to person, device to person, person to device which has given rise to IOT applications. By applying recent internet tech on traditional controlling system, we can create an updated controlling system equipped with internet which would allow us to present, store and accessed all over the globe as live data. Even though we say it is live data it actually carries a small delay due to data transmission. This updated monitoring system is called IOT-based monitoring system. This IOT based monitoring system has been researched, studied and applied widely on several fields including environment, agriculture, transportation, health.

Hydroponics is a modern way of agriculture, Hydroponics is a method of growing plants without soil but using nutrient solution where plant is mechanically supported using things like gravel, rock-wool, coir, sawdust. On comparing Traditional agriculture with hydroponic system, we reap lot of advantages that include maximizing space, conserve water, helps micro climate environment, produces greater yields, requires less work, no need of soil, outputs higher quality and healthy food, cuts down the supply chain, faster crop growth

Considering these advantages, it is suitable for the upcoming era for better supply of quality food with food sustainability. Nutrient solution in reservoir is an important component for the growth of hydroponic plants. The TDS (Total Dissolved Solids) solution is a mixture of hydroponic nutrients and water which is distributed to plants through pipelines. To maintain a hydroponic system, one must observe the quality and quantity of nutrients on regular time interval. Quantity represents the volume which can be observed using on naked eyes but maintaining quality of nutrient solution involves parameters that are represented by parameters such as acidity, temperature, concentration which is measured using pH sensor, temperature sensor and TDS sensor respectively.

Hydroponics is a method of planting where nutrient solution is used instead of soil. The nutrient solution is circulated to plants through lines. Temperature is a major parameter for plant growth. In an hydroponic system it is observed that there are at least 2 types of temperatures the temperature of nutrient solution and the solution of the environment of the plants. The environmental temperature is nothing but the ambient air temperature surrounding the plants. Due to heat isolation of the pipeline and different heat capacity both the temperature may not be the same. Usually, the pipelines are PVC material in a hydroponics plant. PVC is a heat insulator which prevents heat transfer from environment to nutrient solution and conversely. However, the nutrient solution has higher heat capacity than the environment which makes them more inert. Thus, the temperature change should be slower than the environment. The basicity of the nutrient solution is measured using pH meter, pH of a nutrient solution says whether it is basic (>=7) or acidic (<7) in nature. Higher the pH higher the basicity of the solution .It is important to maintain the plant in a pH for optimal growth because it is directly related to the nutrient availability for the plant .The TDS meter uses ion connection method to measure electrical conductivity and provides the ppm value which is particle per million .With this we can understand the amount of nutrition dissolved ,Since an hydroponic plant doesn’t have soil based nutrition the Total dissolved solids in the nutrient solution is the primary and only source of nutrition for the plant .It is vital to maintain this in optimal value for better and healthy growth. Using IoT and maintaining the plant can reduce plant maintenance cost around 23%-70% with increase in growth [6]

2. Background study

There have been several proposals on developing IoT based controlling system for hydroponic maintenance. An IoT based monitor for temperature, volume , concentration and pH of the nutrient solution was developed by [1] which used Arduino Uno as microcontroller and ESP8266 as Wi-Fi module to connect to internet and Raspberry Pi 2B as webserver. these values were available in a web page.

Another hydroponic system named as iHydroIoT from [2] which uses Arduino Uno(microcontroller) to collect data from sensors ,sensors communicate through Bluetooth Low Energy (BLE) module . Raspberry Pi 2(webserver) receives measurements from Arduino Uno which sends the data for visualization to ploty cloud service .This system was to monitor several parameters of nutrients ,air humidity ,acidity , concentration , light intensity, volume and CO_2

Research done by [7] applied IoT specifically to monitor pH and nutrient solution temperature in NFT method which shows condition on LCD ad send notification via SMS gateway and automated control over the pH and oxygen pump actuator . Kularbphttong et al[8] research is a 2 part IoT for hydroponics system where user control vitals such as humidity, light and temperature manually or the system automatically self regulates by checking and refilling

[3] proposes a advanced IoT-based monitoring system for hydroponics which not only performs monitoring but also data analytics using AI (Artificial Intelligence).IT has a complex sensor pack that includes lux, UV ,water ,dissolved oxygen ,CO_2,altitude, electrical conductivity ,pH ,temperature ,water temperature and TDS. The system also collects visual data using 2 cameras. To collect all data from sensors except camera Arduino Mega is used. Raspberry Pi 3B+ is used to collect visual data and to send both measurement and visual data to database via Wi-Fi which is further analyzed using deep learning method to for prediction. Previous research works on this subject show that we are not just restricted to show notification and warnings but it can also help in maintenance using artificial intelligence. The model can make predictions to improve both quality and quantity of the hydroponics production and to make classification

In another hydroponics study [9] nutrient management is forecasted by integrating IoT with Deep Neural Network (DNN) .The DNN model predicts the label based on the table which have 8 labels and the system outputs sensor values, predicted control label with accuracy percentage. In another research by Shekar[10] prediction using machine learning and IoT was conducted.It was a soil based system with automated irrigation system where the machine learning model used KNN to predict the soil condition.

Previous study, article [11], suggests the application of fuzzy logic with IOT for system monitoring and control. The Internet of Things device is utilized to monitor plant conditions and water demands, while fuzzy logic is employed to precisely manage the delivery of water and nourishment. This study also compares the usage of smart management with a traditional way using lettuce and bok choy plants. The results suggest that applying smart control improves plant growth, which is supported by the outward appearance of the plants.

Bayesian Network (BN) was used by Alipio et al. [12] to monitor and regulate a hydroponic system, and they found an improvement in crop output of roughly 67.67% compared to manual fertiliser control. Moisture and temperature sensors have been integrated into an automated system, and (KNN)

Mehra et al. [13] have used a classification machine learning method to analyse and provide predictions about fertiliser and water management. In order to forecast the pH and electric conductivity, which are indicators of the water quality and the variety of nutrients dissolved in it, Herman et al. [14] used Artificial Neural Networks (ANN) .

An IoT-based control system for hydroponic fodder setup was described in another study [15] to monitor and manage water spraying, water level, humidity, water pH, ambient light, and nutrient level. Additional online and mobile applications with a user-friendly graphical user interface (GUI) were created to visualize the sensor data and, if necessary, manually manage the device .

[16] Artificial neural networks have been used in smart farming by Ferentinos and Albright (2007) to regulate the amounts of potenz-hydrogen and electrical conductivity in hydroponic systems. Here, a Feed Forward Neural Model is used to provide two outputs for pH and EC based on nine different inputs. These results show that the Neural Network model correctly predicts the pH and EC values needed to regulate the hydroponics system .

[17] is another study which put out a knowledge distillation-based low-power deep learning model for detecting plant diseases. The suggested low-power model comprised a straightforward shallow neural network topology. The specifications of the additionally, they were decreased by more than 90%. Both the amount of processing needed and the amount of electricity used are decreased. The suggested low-power model obtained a detection accuracy of 99.4% with a maximum power consumption of 6.22 w, which is much less than the current models

3. Proposed Methodology

To measure temperatures, pH, TDS, Humidity of nutrient solution and the surrounding an IoT based controlling system is built. The working concept is explained in Figure 1 . 2 sensors are applied in the system where 3 sensors is immersed in nutrient solution in the pipeline which measure pH, water temperature and TDS and another sensor is placed near the plant to measure the temperature of the environment and Humidity. All measurements are sent to cloud using microcontroller. The data stored in cloud sever is available to be assessed anywhere for authorized users through internet. Data is extracted from thingspekas cloud server and ML algorithm is used to process those data to classify them into classes and make a decision on what has to be done. The proposed model uses stacking method and provides around 95-99% accuracy.

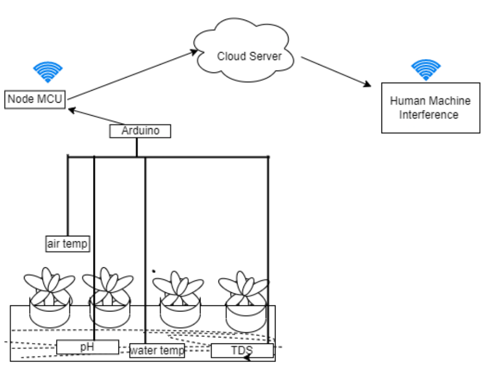

Figure 1: working concept of the hydroponic automation

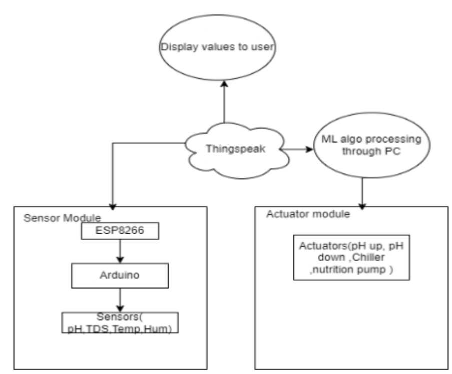

Figure 2: Schematic representation of the proposed system

Circuit Development

We used the Proteus Design Suite 8.11 a proprietary software for electronic and CAD stimulations developed by Labcenter Electronics Ltd Yorkshire England. Proteus has some basic library of electronic components and it also allows user to develop new chip sets, create and import library of specific components to be used. The stimulation was successfully able to read the pH, temperature and humidity but due to unavailability of TDS and Node MCU library we were unable to stimulate both of them, still it’s possible based on already available study done by other researchers.

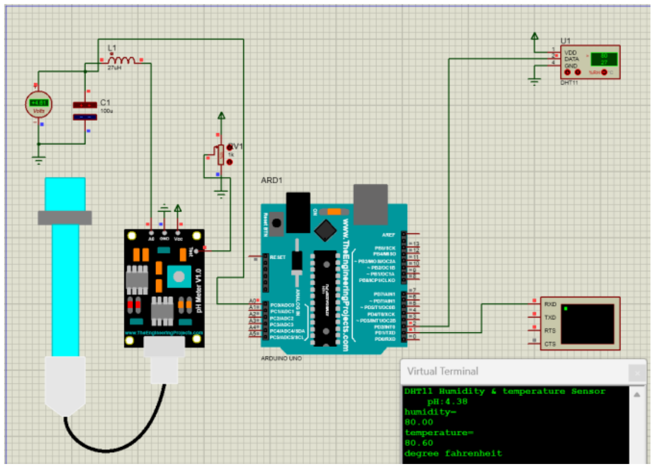

Figure 3: Stimulation of pH meter and DTH sensor

Dataset

We received our dataset from a Hydroponics test plantation system situated in Austria . The live data has been recorded in thingspeaks.com at channel number "1013172”, the data has the following variables "pH, EC, Air temp & Humidity, Water Temp" it also records the time at "created_at". The dataset contains 100 rows of data recorded at every 5 min time interval. The hydroponic test system has 11 leafy plants and a 5-liter nutrient solution reservoir connected to it. While developing the model we noticed that the dataset was not able to be true on 25 conditions out of 28 which means if a model is trained on this data then the output would be only within the remaining 3 conditions that are true .While speaking with the domain expert we also heard that all 28 conditions won’t happen on a real system ,there are chances that few conditions wont happen for lifetime of the product hence we augmented data in such a way that it creates data for every conditions to be satisfied .

The dataset is classified and labeled as shown in Table :1

Label	Condition	Action
1	Normal pH Normal ppm Normal Humidity	Chiller off, TDS up & down pump off, pH up & down pump off
2	High pH Normal ppm Normal Humidity	pH down pump on
3	Normal pH High ppm Normal Humidity	TDS down pump on
4	Normal pH Normal ppm High Humidity	Chiller on
5	Low pH Normal ppm Normal Humidity	pH up pump on
6	Normal pH Low ppm Normal Humidity	Nutrition ab pump on
7	Normal pH Normal ppm Low Humidity	Humidifiers on
8	High pH High ppm Normal Humidity	pH down pump on, TDS down pump on
9	High pH Normal ppm and High Humidity	pH down pump on, chiller on
10	Normal pH High ppm High Humidity	TDS down pump on, chiller on

11	Low pH Low ppm Normal Humidity	pH up pump on , nutrition ab pump on
12	Low pH Normal ppm Low Humidity	pH up pump on, Humidifiers on
13	Normal pH Low ppm Low Humidity	Nutrition ab pump on, Humidifiers on
14	High pH High ppm High Humidity	pH down pump on, TDS down pump on, Dehumidifiers on
15	Low pH Low ppm Low Humidity	pH up pump on, nutrition ab pump on, Humidifiers on
16	High pH High ppm Low Hum	pH down pump on, TDS down pump on, Humidifiers on
17	High pH Low ppm High Hum	pH down pump on, Dehumidifiers on
18	Low pH High ppm High Humidity	pH up pump on, TDS down pump on, Dehumidifiers on
19	Low pH Low ppm and high Humidity	pH up pump on, nutrition ab pump on, Dehumidifiers on
20	Low pH High ppm Low Humidity	pH up pump on, TDS down pump on, Humidifiers on
21	High pH Low ppm Low Humidity	pH down pump on, nutrition ab on, Humidifiers on
22	Low pH high ppm Normal Humidity	pH up pump on, nutrition ab pump on
23	Normal pH Low ppm High Humidity	Nutrition ab pump on, Dehumidifiers on
24	High pH Low ppm Normal Humidity	pH down pump on, nutrition ab pump on
25	Normal pH High ppm Low Humidity	TDS down pump on, Humidifiers on
26	High pH Normal ppm Low Humidity	pH down pump on, Humidifiers on
27	Low pH Normal ppm High Humidity	pH up pump on, Humidifiers on

Model

The existing systems use several other methodologies but no one has used a staking method an ensemble machine learning method which in our stack includes Decision Tree, Random Forest Classifier, K Nearest Neighbor, Multi-Layer Perceptron and it uses Support Vector Classifier as Meta Classifier whose output are passed into a function to interpret the output. Working of the Stacking model is shown in the figure 4.

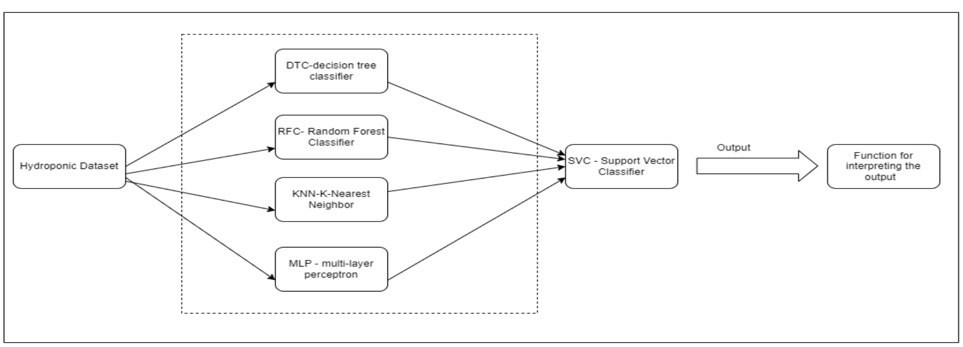

Figure 4 : Working of developed Stacking model that uses .

4. Implementation

From the concept shown in Figure 2 it is clear that the system consist of four main parts : sensors ,microcontroller ,cloud server and Human Machine Interface(HMI). Cloud server is a service on internet for the user end where HMI(It is considered that the HMI is designed based on already available device of the user).Therefore the only hardware requirement of the system is sensors(temperature & humidity sensors ,pH sensor ,TDS meter) ,microcontroller(Arduino) , Wi-Fi module(Node MCU)

The research uses 2 temperature sensors. The temperature sensor that measures the environmental air temperature is called AAT(ambient-air temperature) sensor .The sensor that measures the temperature of nutrient solution is called NST(nutrient-solution temperature) sensor . The NST sensor must be a waterproof temperature sensor.

The DS18B20 is a reasonably priced, waterproof temperature sensor that has a 0.5°C accuracy range from -10°C to +85°C. The DS18B20 is utilized since the AAT sensor is not submerged in liquid, but there is a chance of dew and rain, which might harm non-waterproof sensors. The DS18B20 has three pins, the first of which is ground, the second is data, and the third is VDD. The sensor's power supply ranges from 3.0 to 5.5 volts DC, with the negative voltage linked to pin 1 and the positive voltage attached to pin 3. The output of the temperature data is on pin number two. Pins 2 and 3 need to be linked with a 4.7k resistor in order to work. AAT measures temperature and humidity using a DHT11 sensor.

Water's acidity or alkalinity is determined with a pH sensor, which returns a value between 0 and 14. The water is seen as being more acidic when the pH value drops below seven. The pH of a nutrition solution influences the availability of nutrients; as a result, it should be maintained within the ideal range. The hydrogen-ion activity in a solution is detected using pH probes that have two electrodes (one sensor and one reference). The pH metre monitors the voltage that the ion exchange generates and turns it into a pH value that can be read. A TDS metre is a digital device used to assess water's levels of salt, nutrients, and other elements. This information is crucial for figuring out how much water, food, and oxygen your plants can currently absorb.

Total dissolved solids (TDS), which is referred to as TDS and is measured in PPM (parts per million). It is essentially a measurement of the salt and mineral content of a solution.

Microcontrollers are additional monitoring system hardware. It gathers data from the sensors and transmits it to a Wi-Fi module, which then sends the data to a cloud server. The microcontroller serves as the IoT device's central processing unit and is in charge of handling and controlling all of the sensors. It is a board containing a microprocessor called the Arduino UNO. It has 6 analogue inputs, 14 digital input/output pins (of which 6 may be used as PWM outputs), a USB port, a power connector, an ICSP header, and a reset button. Everything required to support the microcontroller is provided.

Microcontroller and cloud server communication is possible both wirelessly and through wires. For wired connection, LAN (local area network) cables are utilised, however Wi-Fi can be used for wireless communication. When compared to wired connection, wireless communication offers additional benefits, including lower costs, easier installation, and cleaner results.

Although the widely popular microcontroller Arduino lacks Wi-Fi functionality, it may still be utilised by installing a separate Wi-Fi connection module. Node MCU may also function as a standalone microcontroller, however in this research it is solely utilised as a Wi-Fi module to link the entire system to the cloud.

The hardware commponets use C++ code in aurdino and Node MCU to send data to the thinkspeaks server . Cloud server of thingspeaks is one important cloud component of this model where the data is collected in a csv format .It acts as a data base and upon incuding the ml model it can act as server also . The dataset is processed and the model is developed in Python language in a .ipynb notebook environment.The libray used for this include pandas,matplotlib,numpy,random,sklearn .The UI part of the project is developed using streamlit-a Python library.

By training a meta learner to provide a prediction based on many heterogeneous weak learners' which are made to learn in parallel. In stacking, an algorithm learns how to optimally combine the input predictions to get a better output prediction by using the outputs of sub-models as input.

A decision tree is a visual depiction of all options for making a choice in a situation. We attempt to create a condition on the features for each step or node of a classification decision tree in order to fully separate all of the labels or classes present in the dataset. Put the dataset's best attribute at the tree's base. Divide the training set into smaller groups. Each subset of the data should include the same value for each characteristic. This is how subsets should be created. Repeat this process until leaf nodes are visible in all of the tree's branches.

Random Forest is a classifier that uses many decision trees on different subsets of the input dataset and averages them to increase the dataset's prediction accuracy; as such, it is an ensemble learning technique similar to stacking.

The KNN algorithm believes that related objects are located nearby. To put it another way, related items are close to one another. The KNN classifier works by calculating the distances between a query and each example in the data, choosing the K instances that are closest to the query, and then voting for the label with the highest frequency for classification.

A perceptron functions by including certain numerical inputs, as well as what are referred to as weights and a bias. Following that, it multiplies these inputs by the corresponding weights (this is known as the weighted sum). After then, the bias and these products are combined. The more layers in a multilayer perceptron or feedforward neural network, the more processing capability they have and the ability to process non-linear patterns.

In the cross validation procedure, the entire dataset is divided into k equal pieces, each of which is referred to as a fold. Since there are k parts in our model and k = 5 the dataset is divided into k equal pieces, hence the name "k-fold." Other K-1 folds are used for training the model, while one fold is utilized for validation. This process is repeated k times until each fold has been utilized once, using other left-outs as a training set and every fold as a validation set.

5. Results and Discussion

A system that uses IOT where a couple of sensors and internet help us record the data in the hydroponic system and the machine learning model helps us automate the process of monitoring the system The proposed system uses data from thinkspeaks cloud in csv format and performs a ensemble learning using supervised machine learning to build a stacking model consisting of Decision Tree Classifier, Random Forest Classifier, K – Nearest Neighbor, Multi-Layer Perceptron with Support Vector Classifier as final estimator is built and tested using k-fold cross validation method and we get an accuracy score of 97.66% which is satisfactory and acceptable.

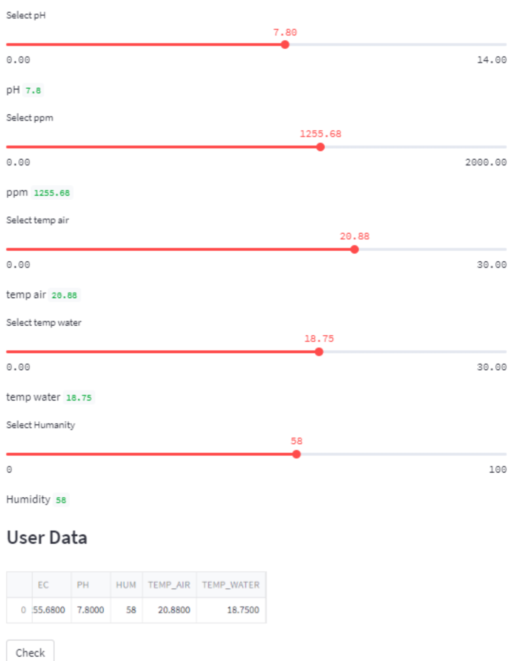

Figure 5: User enters data

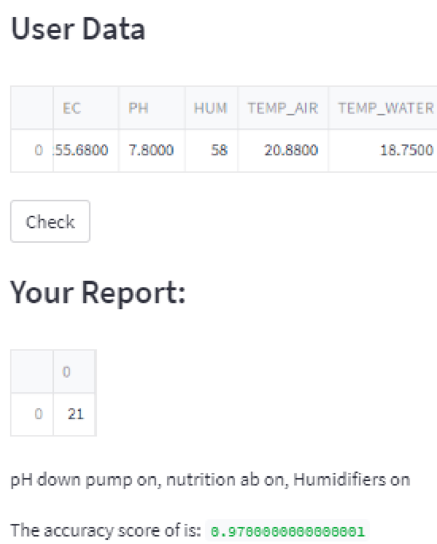

Figure 6 : Overall output of stacking model and accuracy score of the stacking model

6. Conclusion and Future works

This project was carried out to create a hydroponic system on a prototype scale utilising stacks of models and IOT. Using an ensemble learning method, categorise the nutritional condition. The evaluated system shows that the nutritional condition has been accurately classified using the stack model. The classification's output can be used as a command for the actuator module and in real-time situations. The actuator may also turn on or off the nutrition controller simultaneously at a time, in accordance with the label that is categorized. The accuracy of this system may be improved by conducting further experiments to collect data in various scenarios. This model can be deployed in a real time system that's connected to IoT device and runs on cloud ,from where it commands the actuator module .

References

[1] Crisnapati P N, Wardana I N K, Aryanto I K A A and Hermawan A 2017 Hommons: Hydroponic management and monitoring system for an iot based nft farm using web technology 2017 5th International Conference on Cyber and IT Service Management (CITSM) (IEEE) pp 1– 6
[2] Marques G, Aleixo D and Pitarma R 2019 Enhanced hydroponic agriculture environmental monitoring: An internet of things approach International Conference on Computational Science (Springer) pp 658–669
[3] Park S and Kim J 2021 Electronics 10 1400
[4] N Uddin *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **922** 012017
[5]https://www.trees.com/gardening-and-landscaping/advantages-disadvantages-of-hydroponics#Advantages-of-Hydroponics
[6]P. Ahmad and W. S. Pambudi, "Sistem Kontrol Otomatis PH larutan nutrisi tanaman bayam pada hidroponik NFT (Nutrient Film Technique)," J. Ilm. Mikrotek, vol. 2, no. 4, 2018.
[7] J. R. N. Felizardo, A. D. B. Haili, and J. N. S. Payuyao, "Automated Hydroponics System with pH and Temperature Control," 2nd Reg. Conf. Campus Sustain. Capacit. Build. Enhancing Campus Sustain., no. April, pp. 379–386, 2015.
[8]K. Kularbphettong, U. Ampant, and N. Kongrodj, "An Automated Hydroponics System Based on Mobile Application," Int. J. Inf. Educ. Technol., vol. 9, no. 8, pp. 548–552, 2019

[9] M. Mehra, S. Saxena, S. Sankaranarayanan, R. J. Tom, and M. Veeramanikandan, "IoT based hydroponics system using Deep Neural Networks," Comput. Electron. Agric., vol. 155, no. November, pp. 473–486, 2018.
[10] Y. Shekhar, E. Dagur, S. Mishra, R. J. Tom, M. Veeramanikandan, and S. Sankaranarayanan, "Intelligent IoT based automated irrigation system," Int. J. Appl. Eng. Res., vol. 12, no. 18, pp. 7306–7320, 2017
[11] N. Surantha and Herman, "Intelligent Monitoring and Controlling System for Hydroponics Precision Agriculture," 2019 7th Int. Conf. Inf. Commun. Technol., pp. 1–6, 2019
[12] Alipio, M.I., Cruz, A.E.M.D., Doria, J.D.A. and Fruto, R.M.S., 2017, October. A smart hydroponics farming system using exact inference in Bayesian network. In 2017 IEEE 6th Global Conference on Consumer Electronics (GCCE) (pp. 1-5). IEEE.
[13] Mehra, M., Saxena, S., Sankaranarayanan, S., Tom, R.J. and Veeramanikandan, M., 2018. IoT based hydroponics system using Deep Neural Networks. Computers and electronics in agriculture, 155, pp.473-486.
[14] Herman, H., Adidrana, D., Surantha, N. and Suharjito, S., 2019. Hydroponic nutrient control system based on internet of things. CommIT (Communication and Information Technology) Journal, 13(2), pp.105-111.
[15] Muralimohan G, Arjun S V, Sakthivel G ., 2021.Design and Development of IoT based Hydroponic Farming Setup for Production of Green Fodder. Nat.Volatiles&Essent.Oils,2021;8(4):4325-4340.
[16] Ferentinos, K. P., & Albright, L. D. (2002). Predictive neural network modeling of pH and electrical conductivity in deep–trough hydroponics. *Transactions of the ASAE*, *45*(6), 2007.
[17] Uddin, N., Hermawan, H., Darajat, T. M., & Marwanto, S. (2021). Internet-based temperature monitoring system for Hydroponic. *IOP Conference Series: Earth and Environmental Science*, *922*(1), 012017. https://doi.org/10.1088/1755-1315/922/1/012017
[18] D. Adidrana and N. Surantha, "Hydroponic Nutrient Control System based on Internet of Things and K-Nearest Neighbors," 2019 International Conference on Computer, Control, Informatics and its Applications (IC3INA), 2019, pp. 166-171, doi: 10.1109/IC3INA48034.2019.8949585.

[19] https://www.analyticsvidhya.com/blog/2021/08/ensemble-stacking-for-machine-learning-and-deep-learning/
[20] https://towardsdatascience.com/stacking-classifiers-for-higher-predictive-performance-566f963e4840
[21] https://www.turing.com/kb/different-types-of-cross-validations-in-machine-learning-and-their-explanations