# Development of Automated Hydroponic System for Smart Agriculture

**Ajit Dundappa Chachadi[2], G.R. Rajkumar[1]**

[1]*Student, Dept. of Mechanical Engineering, R.V College of Engineering, Bengaluru*
[2]*Professor, Dept. of Mechanical Engineering, R.V College of Engineering, Bengaluru*

---

**Abstract –** *Hydroponic cultivation system has high yield per acre of land with minimal consumption of water and can be a possible means to meet the growing food demand of the world. Hydroponic system is one promising field where internet of things technology (IoT) can be implemented to monitor and control with wireless communication. In this regard, a system capable of running a hydroponic farm autonomously and remotely monitor through mobile application was developed. System architecture is designed consisting of sensors network, Arduino Uno microcontroller, Raspberry pi 4B microcomputer and actuators. Decision tree algorithm was deployed on the Raspberry pi 4B microcomputer to read sensor values from Arduino Uno, process and activate a particular actuator. A mobile application was developed on Android platform to remotely monitor the hydroponic farm*

***Key Words***: Hydroponics, Hydroponic System, Internet of things (IoT), Automation

## 1.INTRODUCTION

Nowadays the ever-increasing rapid urbanization and population increase are resulting in reduced farming lands, water scarcity [1]. The soil based agricultural methods make use of chemical fertilizers which have resulted in degradation of agricultural land. Hence, reduced water usage, recycling of water and fertilizers are need of the hour in the greenhouse industry [2]. The hydroponics or hydroponic system is the solution that can satisfy these needs and this method is already employed in the horticulture. Hydroponics is a plant production technique that does not use soil and make use of water and nutrient solutions only to grow plants. Deep flow technique and nutrient film technique are commercially used hydroponic systems to grow leafy vegetables. [3]. Most plant factories make use of hydroponics because of their added advantage of automated control of fertilization and irrigation which also saves labor. Indoor or greenhouse growing conditions keep the environment clean [4] and control pests and diseases [6]. The booming internet of things (IoT) is becoming area of interest for researchers and industrialists. Increased plant yield and reduced maintenance cost can be observed in hydroponics employing IoT [1].

There has been substantial work being carried on the application of IoT in Hydroponics for sensing, wireless communication and remote monitoring. Arduino microcontroller-based monitoring system was developed to gather data using sensors such as pH sensor, Electrical conductivity sensor [5],[7],[8]. Wireless communications are established using sensors network using Xbee and GBoards pro to control the parameters of Hydroponic system [9]. Water flow control in hydroponics is implemented through use of water flow sensor and servo motors to adjust the required flow. IoT is employed to monitor such a system [10]. The hydroponic climate and nutrient regulation were automated using raspberry pi. Actuators are controlled through Bayesian Network algorithm model based on the of sensor by Alipio et al. [11]. Web interface were developed for accessing, monitoring and controlling via Cloud [11]. Various algorithms based on KNN model [1], Context aware algorithm [10], deep neural networks [12], Fuzzy logic [13] are implemented to control parameters of hydroponic system

The current research aims on controlling change in climate and change in nutrient level due to transpiration and absorption by plants system with internet of things technology. The system makes use of LDR sensor, temperature and humidity sensor for climate monitoring, pH sensor, EC sensor for water quality control. Ultrasonic sensor is used to measure water level. Based on the sensors' measured value, actuators such as submersible pump, peristaltic pumps, circulation fans, and humidifiers are actuated to control various parameters of the system.

## 2. INTERNET OF THINGS

The internet of things is a technology used these days to connect things (hardware) and users with the use of the internet. The data generated by the devices is stored in the cloud for further analysis by the user. The emergence of the internet of things has given an opportunity to automate various systems in agriculture such as irrigation, water quality management and environment management. By employing IoT, the hydroponic system can completely be automated. The hydroponic parameters such as pH, EC, water level, light intensity, temperature and humidity can be monitored and controlled remotely. The data collected from things are sent to cloud for storage. The data from the cloud can be fetched by various mobile devices for purposes such as monitoring, analysis, feedback etc. The real-time monitoring can be done by employing a web interface, iOS application or an android application. Currently, Raspberry Pi microcomputer, Arduino microcontroller and other microcontrollers are made use of to carry out these operations.

## 3. HYDROPONIC SYSTEM

Hydroponics is a soilless agriculture method which grows plants using nutrient solutions consisting of required minerals in water. The plant factories employ hydroponic systems for growing leafy vegetables and other vegetables because of their inherent advantages such as automated irrigation, Low cost of labour, isolated environment, cultivation in layers. Figure 1 shows the schematic of a hydroponic system consists of grow tubes to grow plants, reservoir tank from which the nutrient solution is circulated to the plants. The plants absorb the nutrients and the water falls back into the reservoir. The quality of nutrient solution is measured by Electrical conductivity (EC)sensor and pH sensor. The nutrient pH should be maintained at an optimum level of 6 for proper growth of the plants. pH below 4.5 causes root damage and pH above 7.5 causes precipitation of Fe and Mn. EC sensor helps to maintain nutrient levels of the solution as it is a direct measure of concentration mineral ions in the solution. The cooling fan and humidifier are used to control the climate of the hydroponics namely temperature and humidity respectively.

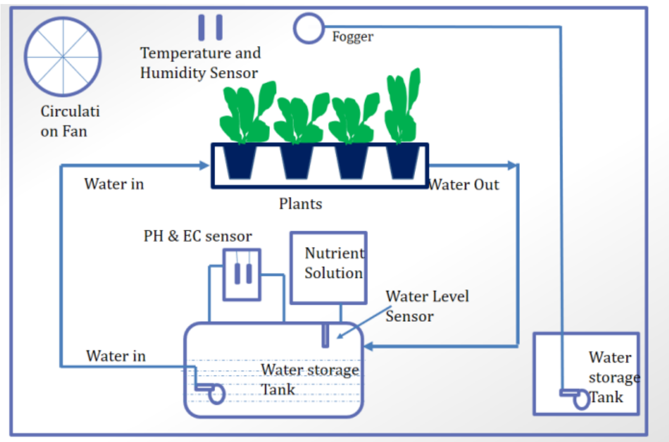


**Fig-1** Schematic of a Hydroponic System

## 4. METHOD

An automated hydroponic system consists of various sensors, actuators and controllers. In order to develop automated system, firstly the data related to hydroponic system parameters and threshold values of nutrients, availability of electronic systems and actuators is gathered. Design of system architecture is done with use of sensors, actuators and controllers. The sensors used are pH sensor, EC sensor, relative humidity sensor, temperature sensor and ultrasonic sensor. The controllers used gather sensor data and control actuators are Arduino UNO microcontroller and Raspberry Pi microcomputer. Arduino connected sensors network is used to read sensor values. Raspberry Pi is used to analyse the gathered sensor data, process it and control the actuators. The data is sent to ThingSpeak cloud platform and is then used to remotely monitor using an Android application in real-time. Decision tree algorithm is implemented to sense and control various sensors and actuators for maintaining the required threshold values in hydroponic system. The sensors, actuators and controllers are assembled as per the system architecture. Developed system is then tested for its functioning under real conditions. Any failures are resolved attending a particular system based on the type of failure. Figure 2 shows flow chart of the methodology used in carrying out the project.

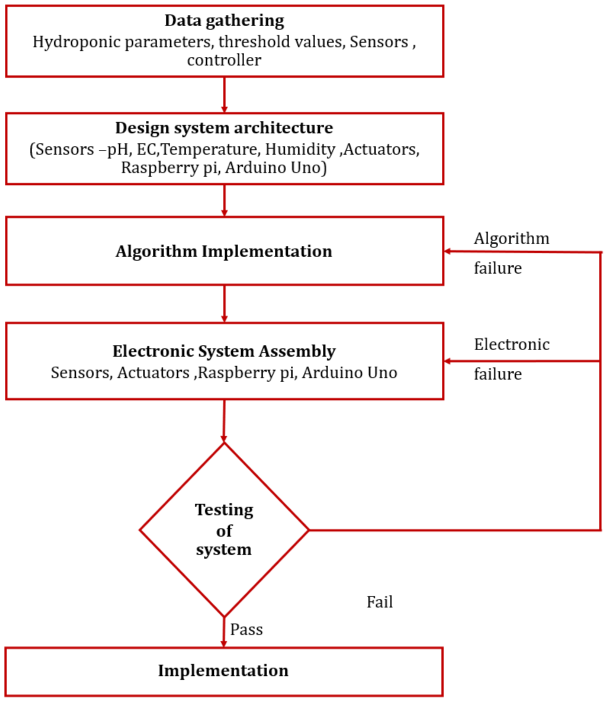


**Fig. 2** Methodology

## 5. SYSTEM ARCHITECTURE

The system architecture consists of all the necessary electrical and electronic components to run a hydroponic farm. The components employed in the system are Raspberry pi microcomputer, Arduino Uno micro controller, sensors and actuators. Figure 3 shows the detailed system architecture used for the work. Sensors used are Kerro make pH sensor, KeyStudio make TDS sensor, DHT11 - temperature and humidity sensor, HC-SR04 distance sensor. Actuators are three peristaltic dosing pumps, circulation pump, cooling and fogger. Two peristaltic pumps are used to increase and decrease the pH and a dosing pump is used to dose nutrient solution into the reservoir tank. Temperature is controlled by cooling fan; humidity is controlled by Humidifier/Fogger and water circulation done by circulation pump. Figure 4 shows electronic circuit board in which the sensors and actuators are assembled as per the system architecture.

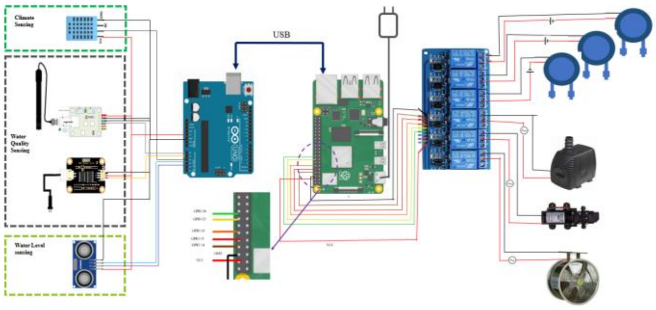

**Fig-3** Detailed system architecture

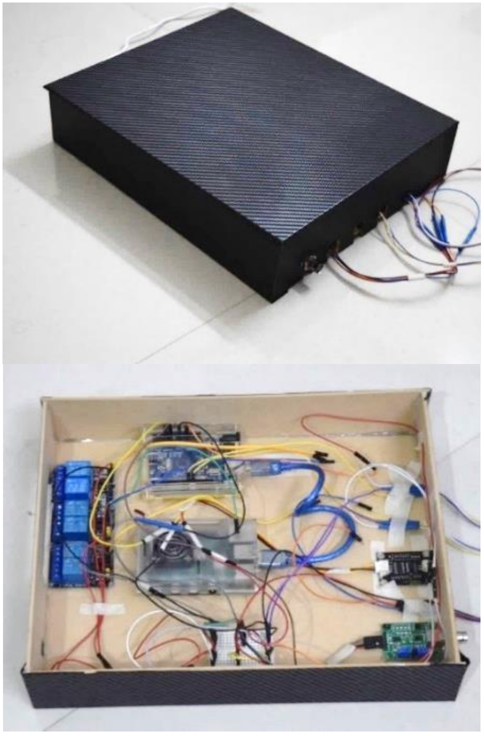

**Fig -4.** Electronic circuit Board

## 6. ALGORITHM

The sensor data gathered by the Arduino Uno is sent to the microcomputer Raspberry Pi 4B through serial communication. Decision tree algorithm was deployed on Raspberry Pi 4B microcomputer to process the data and decide the output actions based on the sensor values received from the Arduino Uno. The figure 5 shows the simplified flowchart of algorithm implemented in the system. The algorithm checks if the sensor values are within the upper and lower threshold limits specified for each parameter. Whenever the parameters are outside the threshold limit, a relay channels are triggered which in turn switch on/off the actuators.

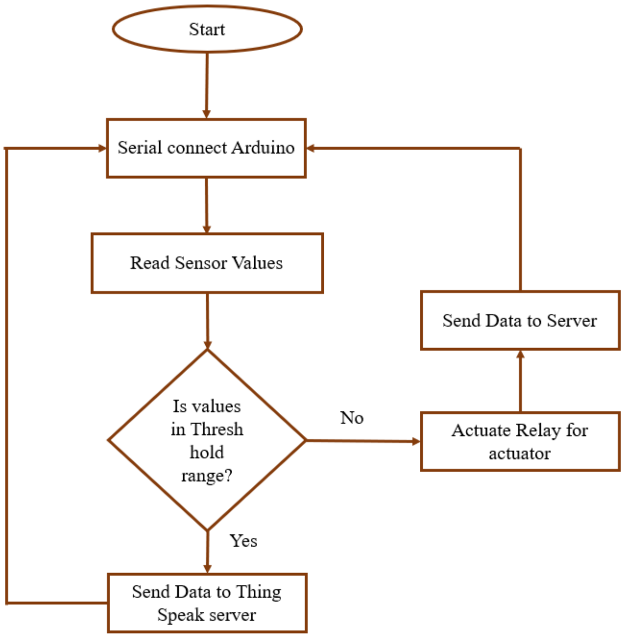


**Fig-5**. Flow chart of algorithm

## 7. MOBILE APPLICATION AND REMOTE MONITORING

The sensors and actuator data are updated to ThingSpeak server in real-time. ThingSpeak is a platform for IoT analytics service which allows to collect, visualise and analyse real-time data streams in the ThingSpeak cloud. ThingSpeak provides instantaneous visualisations of data posted by the devices to server. Figure 6 shows remote monitoring system of data in real-time using ThingSpeak cloud server and mobile device. The update rate is 15 seconds for the free usage of the facility. The remote monitoring system offers real time plotting of the sensor and actuator values for easy remote monitoring by the user.

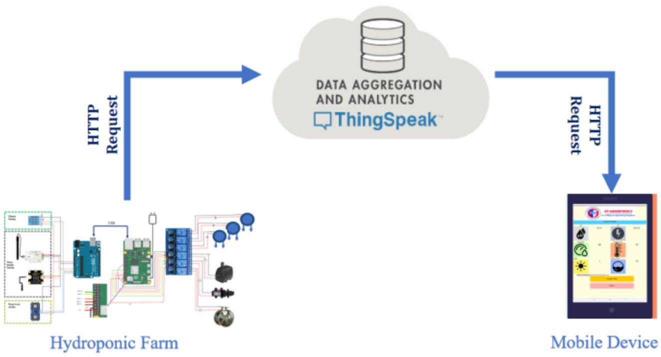


**Fig -6.** Remote monitoring system

The mobile application is developed on the Android platform mainly to monitor the hydroponic parameters and the status of the actuators. The user interface enables the user to view the values of the hydroponic farm parameters through mobile application. The user interface is designed in MIT app inventor which is an online platform to develop mobile applications. The user interface consists of three screens namely to view sensor status, actuator status and the plot of the sensor values for easy analysis. Figures 7 and 8 shows the interface of the sensor status page, actuator status page and sensor plot page respectively.

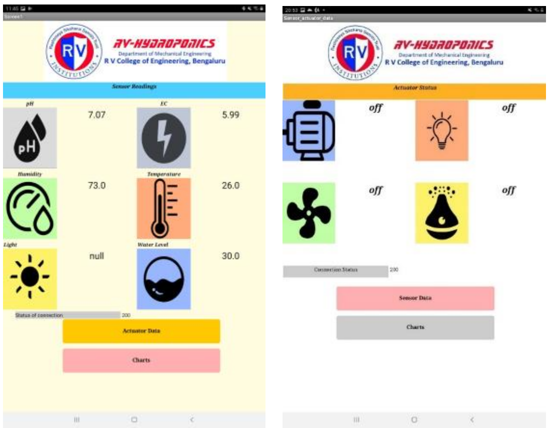

**Fig -7**.User interface actuator and sensor status

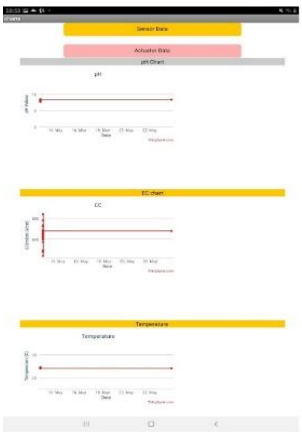

**Fig-8** .User interface of Charts screen

## 8. RESULTS AND DISCUSIONS

The main function of the decision tree algorithm deployed on the microcomputer is to decide output actions based on the sensor input. In order to test the algorithm, sample values were supplied as input with known output to check the output actions from the microcomputer. Table 1 indicates the actuator triggered when sample sensor values are given as input to the algorithm. The algorithm satisfies the expected output action of by triggering an actuator corresponding to senor value outside the threshold limit.

| Sensor Input | | | | Microcomputer Output | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Dosing Pump | | | | |
| Temp ($^0$C) | Humi-dity(%) | pH | EC mS/cm | pH Up | pH Down | Nut-rient | Coo-ling Fan | Humi-difier |
| <30 | <50 | <5 | <2.9 | on | off | on | off | on |
| <30 | <50 | <5 | >2.9 | on | off | off | off | on |
| <30 | <50 | >7.5 | <2.9 | off | on | on | off | on |
| <30 | <50 | >7.5 | >2.9 | off | on | off | off | on |
| <30 | >50 | <5 | <2.9 | on | off | on | off | off |
| <30 | >50 | <5 | >2.9 | on | off | off | off | off |
| <30 | >50 | >7.5 | <2.9 | off | on | on | off | off |
| <30 | >50 | >7.5 | >2.9 | off | on | off | off | off |
| >30 | <50 | <5 | <2.9 | on | off | on | on | on |
| >30 | <50 | <5 | >2.9 | on | off | off | on | on |
| >30 | <50 | >7.5 | <2.9 | off | on | on | on | on |
| >30 | <50 | >7.5 | >2.9 | off | on | off | on | on |
| >30 | >50 | <5 | <2.9 | on | off | on | on | off |
| >30 | >50 | <5 | >2.9 | on | off | off | on | off |
| >30 | >50 | >7.5 | <2.9 | off | on | on | on | off |
| >30 | >50 | >7.5 | >2.9 | off | on | off | on | off |

**Table-1** Actuator trigger output for sensor value input

From table 1 it can be seen that the actuators are activated from the microcomputer with response to the sensor input. For example, the peristaltic pump which doses pH increasing solution is actuated whenever the pH falls below 5.8.

The pH of the nutrient solution changes due to absorption of nutrient ions by the plants for their growth. Higher pH value causes precipitation of Fe and Mn in the solution and lower pH values cause root damage of plants. It is essential to maintain the pH at prescribed level to ensure proper growth of the plants. Chart-1 shows the change of pH value in a given interval of time. It can be seen that pH value read within the hydroponic environment varies from minimum value of 5.85 to maximum value of 5.88 in a given interval of time. The upper and lower threshold limits for hydroponic climate for growing lettuce are 5.50 and 7.0.

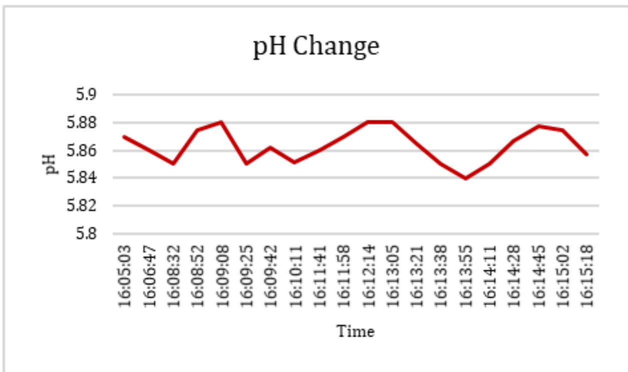


**Chart -1.** Sensor Data of pH with time

The Electrical conductivity of the nutrient solution changes due to absorption of nutrient ions by the plants for their growth. It is very much essential to maintain the electrical conductivity of the hydroponic environment with dosing pump. From Chart-2, it can be seen that EC value within the nutrient solution varies from minimum value of 2.13 mS/cm to maximum value of 2.33 mS/cm. The upper and lower threshold limits for hydroponic climate for growing lettuce are 0.9 mS/cm and 2.9 mS/cm. The maximum and minimum values are within the threshold limits.

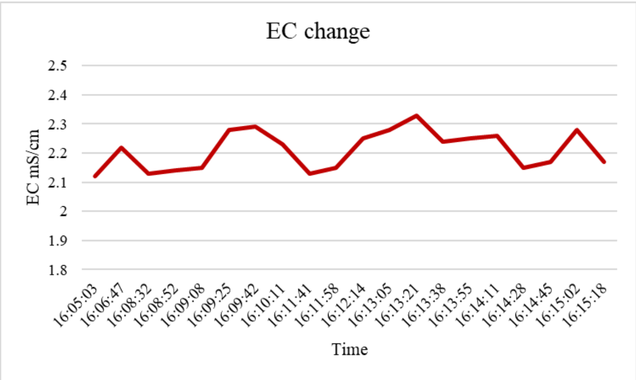


**Chart -2**. Sensor Data of EC with time

The humidity of the hydroponic environment changes due to transpiration and due to change in external environment. It is very much essential to maintain the humidity of the hydroponic environment with the use of cooling fan. From Chart-3 it can be seen that relative humidity within the hydroponic environment varies from minimum value of 65% to maximum value of 69%. The upper and lower threshold limits of humidity of hydroponic climate for growing lettuce are 50% and 80%. The maximum and minimum values are within the threshold limits.

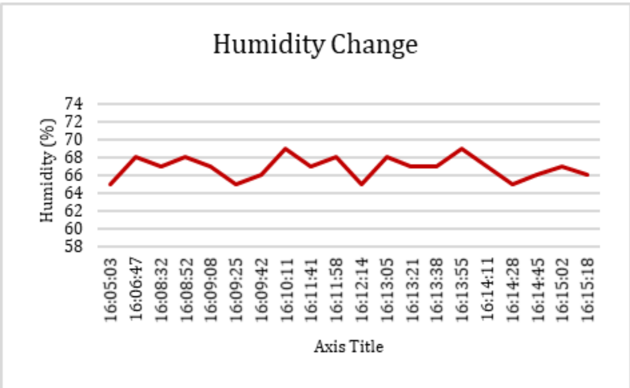


**Chart -3** Sensor Data of Humidity with time

The temperature of the hydroponic environment changes due to transpiration and due to change in external environment. Temperature of the hydroponic environment is maintained with the use of cooling fan. From chart-4, it can be seen that temperature value read within the hydroponic environment varies from minimum of 23-degree C to maximum of 29-degree C for a given interval of time. The upper and lower threshold limits for hydroponic climate for growing lettuce are 23 C and 30C.The maximum and minimum values are maintained within the threshold limits.

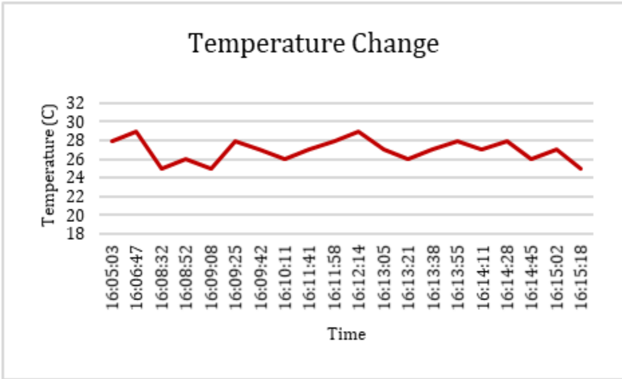


**Chart -4** Sensor Data of Humidity with time

### 9. CONCLUSIONS

The advancements in Horticulture with the use of Technology can impact the economy significantly. Hence this project focuses on developing a hydroponic system which can run hydroponic farm autonomously and allows monitoring of the farm remotely by the user. Based on the study of hydroponic system for lettuce, the following conclusions are drawn.

- A system employing decision tree algorithm deployed on Raspberry pi 4B microcomputer was developed. The system can autonomously run and remotely monitor a hydroponic farm.
- Mobile application was developed and deployed on the Android platform to remotely monitor the hydroponic farm. This made the farmer to maintain large farms.
- The results show that the system maintains hydroponic parameters pH, EC, temperature and humidity at an average value of 5.86,2.21 mS/cm, 26.95 $^0$C and 66.85% respectively.

### ACKNOWLEDGEMENT

We take this platform to thank Head of the Department, Dr. M. Krishna for his valuable suggestions and support in carrying out the research work and providing facilities in the Department. We thank Dr. K N Subramanya, Principal, R.V.C.E, for fostering excellent academic atmosphere in the campus.

### REFERENCES

[1.] 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.

[2] P. P. Giaglaras, Ch. Lykas, C. Kittas, Dynamic Simulation of Nutrient Solution Composition in a Closed Hydroponics System,IFAC Proceedings Volumes,Volume31, Issue 12,1998,Pages 219-224.

[3] Jung Eek Son, Hak Jin Kim, Tae In Ahn, Chapter 20 - Hydroponic systems,Editor(s): Toyoki Kozai, Genhua Niu,

Michiko Takagaki,Plant Factory (Second Edition),Academic Press,2020,Pages 273-283.

[4] Teruo Wada,Chapter 1.1 - Theory and Technology to Control the Nutrient Solution of Hydroponics,Editor(s): Masakazu Anpo, Hirokazu Fukuda, Teruo Wada,Plant Factory Using Artificial Light,Elsevier,2019,Pages 5-14.

[5] B. Siregar, S. Efendi, H. Pranoto, R. Ginting, U. Andayani and F. Fahmi, "Remote monitoring system for hydroponic planting media," *2017 International Conference on ICT for Smart Society (ICISS)*, 2017, pp. 1-6.

[6] T. Nishimura, Y. Okuyama and A. Satoh, "High-accuracy and low-cost sensor module for hydroponic culture system," *2016 IEEE 5th Global Conference on Consumer Electronics*, 2016, pp. 1-4.

[7] Iswanto, P. Megantoro and A. Ma'arif, "Nutrient Film Technique for Automatic Hydroponic System Based on Arduino," *2020 2nd International Conference on Industrial Electrical and Electronics (ICIEE)*, 2020, pp. 84-86.

[8] S. Ruengittinun, S. Phongsamsuan and P. Sureeratanakorn, "Applied internet of thing for smart hydroponic farming ecosystem (HFE)," *2017 10th International Conference on Ubi-media Computing and Workshops (Ubi-Media)*, 2017, pp. 1-4.

[9] Helmy, M. G. Mahaidayu, A. Nursyahid, T. A. Setyawan and A. Hasan, "Nutrient Film Technique (NFT) hydroponic monitoring system based on wireless sensor network," *2017 IEEE International Conference on Communication, Networks and Satellite (Comnetsat)*, 2017, pp. 81-84.

[10] O. Gandhi, M. Ramdhani, M. A. Murti and C. Setianingsih, "Water Flow Control System Based on Context Aware Algorithm and IoT for Hydroponic," *2019 IEEE International Conference on Internet of Things and Intelligence System (IoTaIS)*, 2019, pp. 212-217.

[11] Melchizedek I. Alipio, Allen Earl M. Dela Cruz, Jess David A. Doria, Rowena Maria S. Fruto, On the design of Nutrient Film Technique hydroponics farm for smart agriculture, Engineering in Agriculture, Environment and Food, Volume 12, Issue 3, 2019, Pages 315-324.

[12] Manav Mehra, Sameer Saxena, Suresh Sankaranarayanan, Rijo Jackson Tom, M. Veeramanikandan, IoT based hydroponics system using Deep Neural Networks,Computers and Electronics in Agriculture,Volume 155,2018,Pages 473-486.

[13] S. Mashumah, M. Rivai and A. N. Irfansyah, "Nutrient Film Technique based Hydroponic System Using Fuzzy Logic Control," *2018 International Seminar on Intelligent Technology and Its Applications (ISITIA)*, 2018, pp. 387-390.