Implementation of IoT in Agriculture: A Scientific Approach for Smart Irrigation

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***Abstract*— Digital technologies empower the transformation into data-driven, intelligent, agile, and autonomous farm operations and are typically considered a key to addressing the grand challenges in agriculture. To avoid unscientific water supply for plantation as well as to save the water and also yield the better crop, therefore, to increase production efficiency out of smart irrigation and to send the status of irrigation at standard environmental conditions, The Internet of Things (IoT) based prototype is designed and implemented. The prototype automatically turns ON /OFF the motor pump based on the moisture level of the soil by taking the temperature and humidity of the environment near the plantation into consideration (In India, the standard parameters for watering the vegetable plantation are Humidity>60%, Temperature < 25°C and Humidity<40%). The prototype is designed with an ESP32S microcontroller with DHT 11 and a moisture sensor. Arduino IDE development tool is used for programming ESP32S using embedded C programming language. The prototype is configured, programmed, and connected to the Arduino IoT cloud. The data of temperature, humidity, and moisture are received via message queuing telemetry transport (MQTT) protocol on IoT cloud through public IP therefore the data can be accessed worldwide. The authorized person can access the data and control the motor pump from anywhere across the world. The test data obtained out of the prototype over the cloud and at the system are presented in the result section.**

Keywords*— *Smart irrigation, IoT Cloud, Moisture sensor, Temperature sensor, MQTT, Cloud Computing

I. INTRODUCTION

Smart farming involves the addition of the latest technologies like artificial intelligence (AI) and machine learning (ML) with IoT cloud into the existing practices in farming. This results in increasing the production of crops as well as efficiency in the management of farming. There are many benefits out of using IoT in farming. IoT in farming finds the effective use of equipment, employees, and whole business in general since IoT systems are capable to track the whole Business in general in farming. In fact, this kind of technology in farming reduces the faults in production and

Predicts the output of production. This of course allows for having plan better distribution [1].When we are able to predict how much we are going to harvest from farming then there is no scope for lying around unsold things of crops and finding the anomalies in the growth of crops [2]. This again results in mitigating the issues connected with losing the yields of crops. Using AI and ML with IoT in agriculture automates multiple processes across the production stage. For example smart water irrigation, smart disease detection of the plantation, livestock, and real-time prediction of growth of plantation. All these things lead to high standards of quality of crops via automation. Eventually, all these techniques help in farming to have higher revenue [3].

Internet of things basically refers to the typical physical devices in agriculture are microcontrollers (The typical microcontroller like ESP32 has built Wi-Fi and classic Bluetooth), Sensors like temperature and humidity sensors, moisture sensors and finally, actuators like a buzzer, relay, and led and so on are connected together forms perception layer for sharing data among themselves and sending the data to the next layer depends on the architecture of IoT chosen while designing the system. The main objective of using IoT is to ease up everyone's tasks if they are complex in different perspectives [4].Therefore having devices around us that are capable of having networking features can form a system that is smart enough to serve the application for that matter [5]. In the ecosystem of IoT, there is no standard or single architecture to be followed. Each organization uses its own protocols across the world therefore IoT is not gaining its own importance just because of the issue mentioned above. The reason behind that is each user, each company, or organization has its own requirements. Therefore based on the requirements the ecosystem is divided into simple three-level architecture as shown in figure 1 which is the basic and first level of architecture in the ecosystem of IoT [6]. This kind of architecture contains three layers starting from the perception layer at the bottom and the application layer at the top. In between these two layers, there is a network layer. The perception layer at the bottom is the first layer as an entry point where all physical components including sensors present. The sensors gather the information which will be later collected by the control unit and this control unit apply logic and send the modulated data to the network layer. The network layer further learns itself and passes the modulated data received from the perception layer to the application layer [7]. The application layer later converts the modulated data to a form that can be readable by the end-user or end platform.

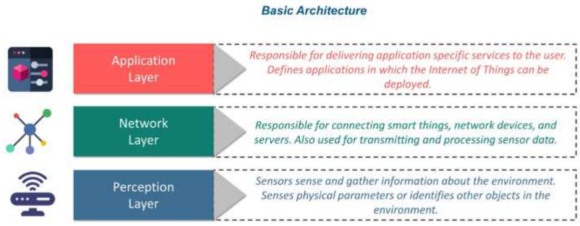

Fig.1. Three layer architecture of IOT

The three layer architecture can be updated to five layer architecture as shown in figure 2. The five layer architecture is quite same as three layer architecture .The only difference is adding three new layers such as transportation layer, processing layer and business layer in place of network layer. In five layer architecture, the top most layer is business layer and the bottom most layer is perception layer. Again the job of perception layer here is remains same while the new layer i.e. transport layer which takes the data from perception layer and pass it on to processing layer. The transport layer is formed with wireless protocols such as Bluetooth, RFID, 5G, and NFC [8]. The processing layer does the job of storing, analyzing, processing huge amount of data and cloud computing. At present scenario there widely used cloud systems such as, Microsoft Azure, AWS, ThingSpeak and Arduino IoT cloud. Once cloud computing is done with processing layer, the modulated data received is passed on to application layer where the user readable data will be delivered to end users. Finally the business layer comes into picture in case of big organization .It does the job of monitoring large number of actuators connected at the perception layer and pass the information about the actuators to the end users via customer care centers. Basically the business layer manages the whole IoT ecosystem which includes application layer and profit models along with maintaining the privacy of end users [9].

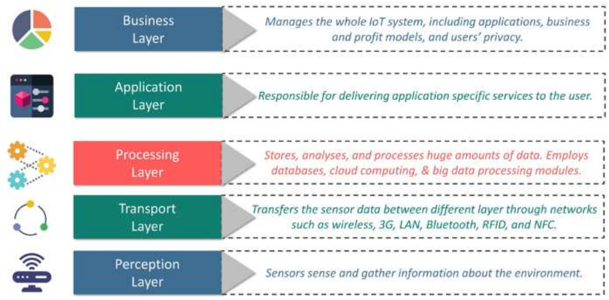

Fig.2. Five layer IoT Architecture

Now coming down to how this can be processed using cloud computing-based processing as shown in figure 3, where the data received is sent to the cloud, once data is loaded in the cloud platform and it will be used for processing and applied on to the various applications. This will helps to get the data and to take any action anywhere at any time within very less amount of processing time. There are various sectors in which this technology can be used are home automation, autonomous vehicles, controlling of home appliances, and building security at office premises.

Fig.3. Cloud computing

When the system needs immediate response use the fog computing technology which is shown in figure 4. The fog computing technologies is based on a layered approach here the various process such as insert monitoring, preprocessing, and storage are accommodated within the security layer between the physical and transport layers.

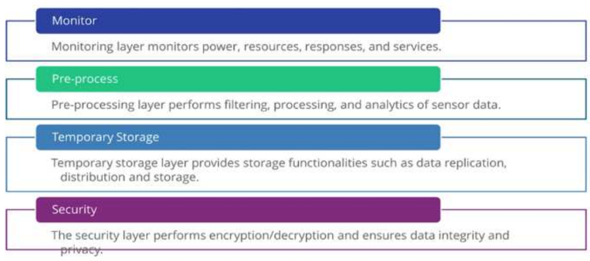

Fig.4. Fog computing in IoT

In addition to these two layers, the four new layers are added to the security layer as shown in figure5. This will add the advantages such as the system will be smarter or very effective with respect to security. Now at the security layer in addition to the physical and transport layers, there few layers such as the monitoring layer, preprocessing layer, storage layer, and security layer.

Now let us discuss the real-time example, consider a traffic system that is built using IoT technology. Let us consider the scenario where the ambulance has to cross the signal as the first priority. We detect the ambulance location by getting the data that was stored in the cloud by the sensor implemented in that location where the ambulance is present. This data has to be processed and the corresponding map to be provided to make the ambulance to cross the signal with the highest priority. The information or sensor data collected from the sensor will be sent through the gateway where it will be preprocessed. This data will be stored in the cloud and sent back to the sensors as well. With the help of the data stored in the cloud, the nearby hospitals can create a track to reach the hospital as early as possible. In this case, security is very essential because the data stored.

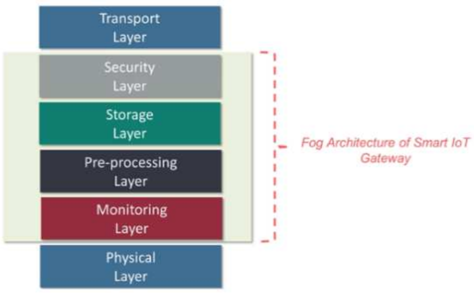

Fig.5. Fog Architecture in IoT

Now we will discuss the various taxonomies used in association with the Internet of Things. There are a few key layers that are present in most of the architectures of the Internet of Things.

This idea provides the flexibility to use the customized systems depending on their own ideas to solve the problems, but few of these layers are needed as fundamental layers to build any architecture. Firstly we have the perception layer, in this layer, we collect the information from various sensors which are connected to the system. Secondly, we have a processing layer here we will do the filtering operation to finalize the data to do the analytics before sending it to the systems for processing. We have a Communication layer to decide the communication protocols and standards used as a medium for sending the data from the sensors to the system. The middleware plays an important role at this level, which is responsible for the system operating much smoother than earlier by integrating in the information received by the various sensors connected to the system. This data will be passed on to the application layer to improve the overall performance by providing more accuracy and efficiency.

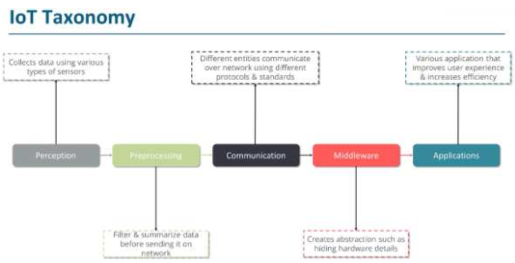

Fig.6. IoT Taxonomy

II. Related Work

Andrés Villa-Henriksen [10] ,describes the internet of things in farming. Discussed about widely used communication protocols in the infrastructure layer and application layer connected to smart agriculture. The wireless technologies in infrastructure layer are IEEE 802.15.4 which is used by ZigBee or 6LowPAN or 3GPP used by GPRS, LTE or 5G. In application layer, the protocols such as HTTP, MQTT and XMPP are commonly used in IoT applications in farming. Implementing protocols is challenging since the way they are used in each application is different just like in vehicle to vehicle communication. The protocols supposed to be carefully employed as they are not always compatible and can have effect on data formats or sensors and gateways used. To simplify such issues we have middleware platforms which can integrate the diverse protocols by offering abstraction levels.

Chatzikostas, G., et al. [11] explains the smart agricultural hub contains internet of food and farm. The smart hub connects local hubs to be able to carry out high-performance innovation experiments.

Seyyedhasani , et al. [12] infers the breaking down the fields into paths that can be used by the vehicles which are meant for agricultural operations therefore the efficiency of operations get increased .Here two important routing algorithms are used for the purpose of field division scientifically. The algorithms are fast Clarke-Wright heuristic and slower tabu search meta-heuristic.

Wolanin, Aleksandra, et al [13] describes the estimation of crops in agriculture using machine learning models in Sentinel-2 and Landsat 8 technology. The highlights of this paper is that it conducted on 1200 scenarios via simulation using routing algorithms. The scenarios are based on size, shape and path generated methods.

Laghari, A.A., Wu, K., Laghari, R.A. et al. [14] explains the importance of IoT in smart farming. Farmers can control the water supply for plants and getting the information about moisture level and nutrients of soil using IoT .this helps the farmer to increase their income level by reducing cost for farming.

A.G. El-Naggar, et al [15] infers the use of IoT with LiDAR technology to exact estimation of crop growth and water usage. Also find out the spatial variation in the crop growth pattern. Terrestrial laser scanner is used for measuring crop height and biomass of a bean crop. This method has potential to measure the height surface of crop.

R. Venkatesan et al [16] describes the IoT verticals towards water management in agriculture where the system can collect the data like environmental temperature, humidity, soil moisture level. The technology used in this paper is Wi-Fi and ZigBee. The challenges in the current approach is that human interaction, labour cost and wastage of water. So the solution is to find the said parameters and control the water automatically to save it.

III. Design and Methodology

A. Hardware

The hardware components shown in table.1 are used in the implementation of the prototype. The approximate cost also mentioned for reference. The complete architecture designed for IoT cloud based smart irrigation system is as shown in figure.7.

i). ESP32S: Its Microcontroller contains wireless protocols like Wi-Fi, Bluetooth. It has sufficient GPIO pins along with ADC channels. Therefore analog and digital sensors can be easily interfaced with this device. It supports Embedded C program as well as MicroPython. It is mainly used in IoT applications like industrial automation, smart home, smart agriculture, and IP camera and so on [17].

ii). DHT 11 sensor: Its three terminal device. Data terminal is connected to ADC channel of microcontroller and remaining two terminals connected to 5V-3V DC and Ground respectively. This device is used to measures Temperature and humidity of soil in this context. Data terminal is connected to GPIO 15 of ESP32S device. The GPIO 15 is basically ADC channel 13 [18].

iii). Soil Moisture Sensor: It is also having three terminals. One is data terminal and other two are 5V DC and Ground terminal. This is used to measure moisture level of soil. This device is connected to GPIO 36 of ESP32s device. The GPIO 36 is basically ADC channel 0.

iv). Submersible Mini Water Pump: Its low cost, small size water pump operates with 5-12 V DC supply and current of 130-220mA. It can take up to 120 liters per hour with current consumption of 220mA.while using this motor, care should be taken to avoid dry run since it damage the motor due to heating [19].

v). relay: The single channel relay is used to control motor via 5V battery with 180mA current. Based on the control signal from microcontroller, the relay can switch the battery to submersible mini water pump [20].

vi). 5V Battery: It is used to power up the motor with current of 130-220mA since ESP32S cannot provide the required current for the submersible mini water pump.

vii). Wi-Fi-gateway: It is used to provide internet for the microcontroller. In this implementation mobile device with 4G GSM is used to provide internet.

viii). Arduino IoT cloud: Its cloud platform used to configure required things in our prototype design. In this case, four things are configured over cloud. The things such as Temperature, Humidity, Moisture and Motor control .Once the configuration for things is done, Arduino cloud will generate some default code which need to be further edited as per our requirements. Later microcontroller board to be connected host for programming [21].

ix).User Login: Once it is programmed successfully, we need to look into things in cloud platform to check the parameters like temperature and humidity as well as moisture level. According to these parameter, motor can turn ON and turn OFF automatically. If user wish to turn ON or turn OFF by ignoring the parameter can also be done.

B. *Software*

The program logic is expressed in terms of Flowchart is as shown in figure 8. It defines Arduino cloud library like"thinkProperites.h".This library support the things which are defined by the user over the cloud. One more library is DHT.h which supports DHT 11 device. Once all the libraries and variables are defined, it will check for Temperature, Humidity and Moisture level of soil. It will turn 'ON' the motor only if it is satisfied with three parameters such as Temperature is less than 30^{O} C , Humidity is more than 60% and moisture level is less than 40%.

The system controls the motor based on the condition given in the table.1. Level of rating for moisture, temperature and humidity are fixed based on the Indian standard for vegetable plantation.

TABLE.I DESIGN SPECIFICATIONS

Sl.No	Component	Quantity	Approximate Cost in INR
1	ESP32S	1	700
2	DHT11 Sensor	1	120
3	Soil Moisture Sensor	1	180
4	Submersible Mini water Pump	1	60
5	Relay	1	50
6	5V Battery	1	200
7	Android Mobile as Wi-Fi Gateway	1	User mobile
8	Arduino IoT cloud	1	Free (Limited)
9	User login for data analytics.	1	User laptop

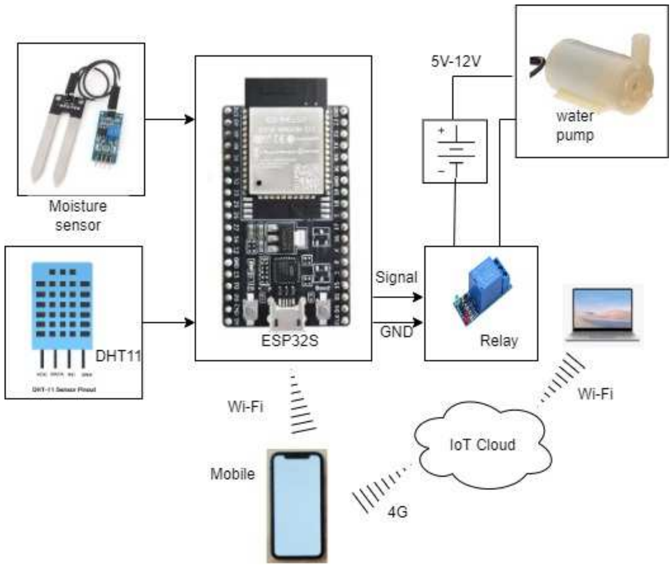

Fig.7. Architecture of Smart irrigation with IoT Cloud

IV. Results and Discussion

The hardware setup is as shown in figure. 9 with clear labelling of each module used in building prototype. The porotype is tested for automatic motor control based on moisture level of soil and temperature and humidity at environment. The testing is done for moisture sensor in two cases i).By placing sensor in a container having water to measure the moisture level. ii). By placing the moisture sensor outside the container having water. The prototype is working perfectly. In India, the standard humidity and temperature & humidity levels for vegetable plantations are as follows: Humidity level supposed to be more than 60%, Moisture level supposed to be more than 40 % and Temperature supposed to be less than 30° Celsius. The motor pump is turning ON as well as turning OFF based on moisture level and also temperature and humidity at environment. The automatic motor control based on parameters and conditions are as shown in the table.2.Four IoT things present in prototype are configured Arduino IoT cloud as shown in figure.10. Programming is done over IoT cloud for the prototype as shown in figure.11.The data of moisture, temperature and humidity parameters are obtained on Arduino IoT cloud as shown in fig.12 .The data obtained at prototype side is as shown in figure 13.

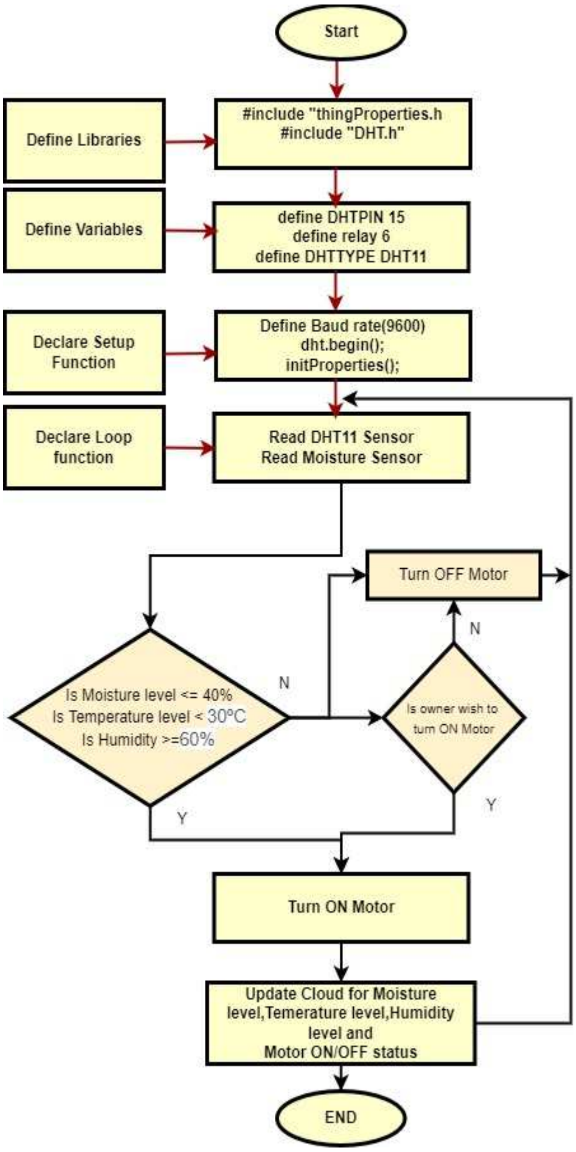

Fig.8. Logic used in smart irrigation with IoT

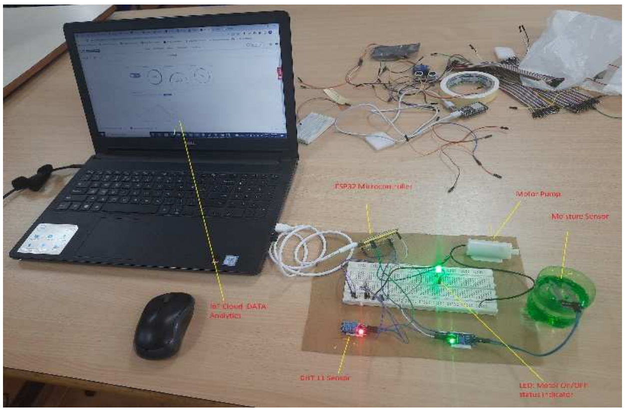

Fig.9. Hardware Test Bench Setup

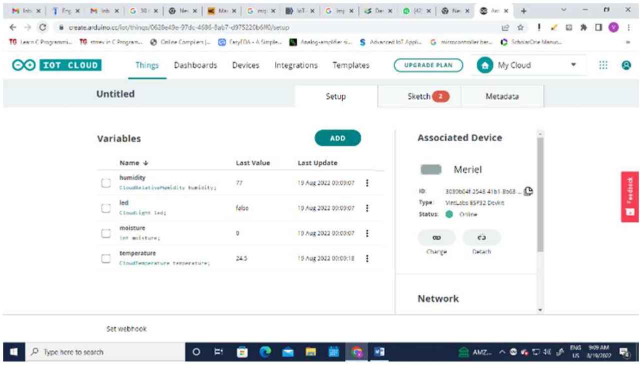

Fig.10. Configuration of prototype in IoT cloud

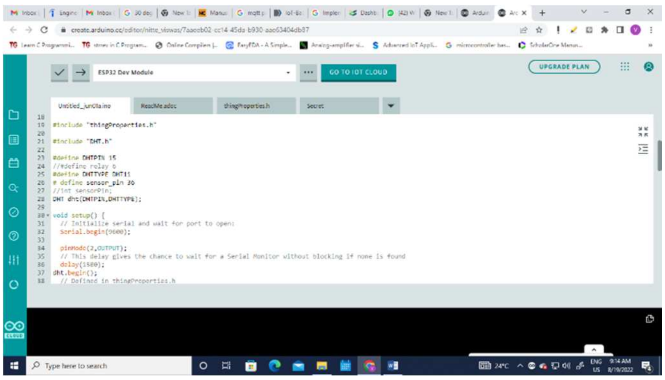

Fig.11. Programming prototype in IoT cloud

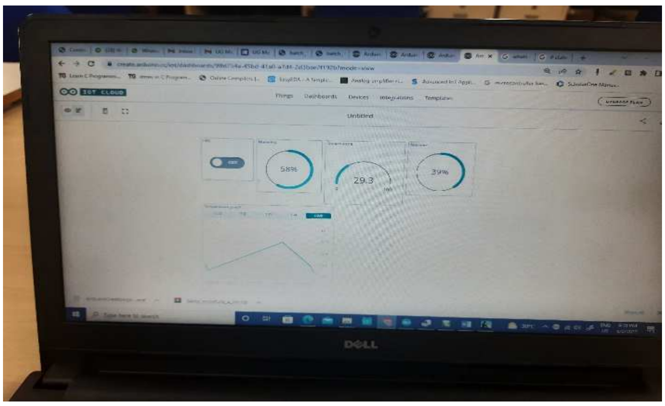

Fig.12. Data received at Arduino IoT cloud

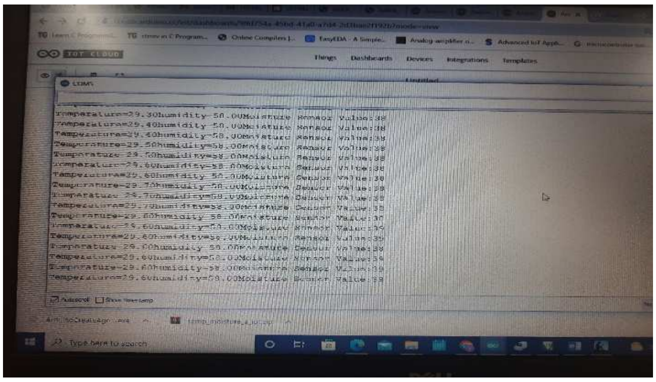

Fig.13. Data obtained at prototype side

TABLE.II AUTOMATIC MOTOR CONTROL CONDITIONS

SL.No	Moisture Level (%)	Temperature ^{0}C	Humidity (%)	Motor Status
1	< 40	< 30	> 60	ON
2	>40	> 30	< 60	OFF
3	> 40	> 30	> 60	OFF
4	> 40	< 30	< 60	OFF
5	> 40	< 30	> 60	OFF
6	< 40	> 30	< 60	OFF
7	< 40	> 30	> 60	OFF
8	< 40	< 30	< 60	OFF

V. CONCLUSION AND FUTURE SCOPE

The rise and development of IoT and its cloud computing feature for agriculture with tiny microcontrollers bring prototype with cost effective as well as efficiency in production. This system provide information correctly and timely since this system with IoT and cloud has certain advantages like small size, light weight, low noise, high reliable ,speed and low maintenance cost therefore the formers will handle it efficiently. This will be a great development for formers. The programming is simple to implement the applications using the Arduino IoT cloud for the Agriculture applications wirelessly using ESP32S microcontroller as it has wireless technologies like Wi-Fi and Bluetooth. Besides, the prototype is stable and reliable than the traditional ones. Its maximum speed of printing can be up to 80mm per second. The system has highly adaptability. It can be used in many situations not only for smart irrigation Further this system can be extended for internet of things (IoT) with TinyML based control with better accuracy and efficiency .

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REFERENCES

[1] F. Guo, F. R. Yu, H. Zhang, X. Li, H. Ji and V. C. M. Leung, "Enabling Massive IoT Toward 6G: A Comprehensive Survey," in IEEE Internet of Things Journal, vol. 8, no. 15, pp. 11891-11915, 1 Aug.1, 2021.

[2] J. Ruan et al., "A Life Cycle Framework of Green IoT-Based Agriculture and Its Finance, Operation, and Management Issues," in IEEE Communications Magazine, vol. 57, no. 3, pp. 90-96, March 2019.

[3] Madushanki, AA Raneesha, et al. "Adoption of the Internet of Things (IoT) in agriculture and smart farming towards urban greening: A review." International Journal of Advanced Computer Science and Applications 10.4 (2019).

[4] Viswanatha, V., Ashwini Kumari, and Pradeep Kumar. "Internet of things (IoT) based multilevel drunken driving detection and prevention system using Raspberry Pi 3." International Journal of Internet of Things and Web Services 6 (2021).

[5] A. Vangala, A. K. Das, N. Kumar and M. Alazab, "Smart Secure Sensing for IoT-Based Agriculture: Blockchain Perspective," in IEEE Sensors Journal, vol. 21, no. 16, pp. 17591-17607, 15 Aug.15, 2021.

[6] B. Parvez, R. A. Haidri and J. Kumar Verma, "IoT in Agriculture," 2020 International Conference on Computational Performance Evaluation (ComPE), 2020, pp. 844-847.

[7] Lakhwani, K., Gianey, H., Agarwal, N., Gupta, S. "Development of IoT for Smart Agriculture a Review", In: Rathore, V., Worring, M., Mishra, D., Joshi, A., Maheshwari, S. (eds) Emerging Trends in Expert Applications and Security. Advances in Intelligent Systems and Computing, vol 841, (2019).

[8] Symeonaki, Eleni, Konstantinos Arvanitis, and Dimitrios Piromalis. "A context-aware middleware cloud approach for integrating precision farming facilities into the IoT toward agriculture 4.0." Applied Sciences 10.3 (2020).

[9] He Jiang, Xiaoru Li, Fatemeh Safara, IoT-based Agriculture: Deep Learning in Detecting Apple Fruit Diseases, Microprocessors and Microsystems, 2021.

[10] Andrés Villa-Henriksen, Gareth T.C. Edwards, Liisa A. Pesonen, Ole Green, Claus Aage Grøn Sørensen, Internet of Things in arable farming: Implementation, applications, challenges and potential, Biosystems Engineering,Volume 191, 2020, Pages 60-84.

[11] Chatzikostas, G., et al. "Smart agri hubs D3. 1 innovation experiment guidelines." (2019).

[12] Seyyedhasani, Hasan, Joseph S. Dvorak, and Eric Roemmele. "Routing algorithm selection for field coverage planning based on field shape and fleet size." Computers and Electronics in Agriculture 156 (2019): 523-529.

[13] Wolanin, Aleksandra, et al. "Estimating crop primary productivity with Sentinel-2 and Landsat 8 using machine learning methods trained with radiative transfer simulations." Remote sensing of environment 225 (2019): 441-457.

[14] Laghari, A.A., Wu, K., Laghari, R.A. et al. A Review and State of Art of Internet of Things (IoT). Arch Computat Methods Eng 29, 1395–1413 (2022).

[15] A.G. El-Naggar, B. Jolly, C.B. Hedley, D. Horne, P. Roudier, B.E. Clothier,The use of terrestrial LiDAR to monitor crop growth and account for within-field variability of crop coefficients and water use, Computers and Electronics in Agriculture,Volume 190, 2021.

[16] R. Venkatesan and A. Tamilvanan, "A sustainable agricultural system using IoT," in International Conference on Communication and Signal Processing (ICCSP), 2017.

[17] Viswanatha, V., and R. Venkata Siva Reddy. "Digital control of buck converter using arduino microcontroller for low power applications." 2017 International Conference On Smart Technologies For Smart Nation (SmartTechCon). IEEE, 2017.

[18] Viswanatha, V., and R. Venkata Siva Reddy. "Research on state space modeling, stability analysis and PID/PIDN Control of DC–DC converter for digital implementation." Advances in Electrical and Computer Technologies. Springer, Singapore, 2020. 1255-1272.

[19] Viswanatha, V. "Stability and Dynamic Response of Analog and Digital Control loops of Bidirectional buck-boost Converter for Renewable Energy Applications." International Journal of Recent Technology and Engineering , Volume-8 Issue-2, July (2019).

[20] Nayak, J. P., Anitha, K., Parameshachari, B. D., Rashmi, P. (2017, August). PCB Fault detection using Image processing. In IOP Conference Series: Materials Science and Engineering (Vol. 225, No. 1, p. 012244). IOP Publishing

[21] Parameshachari, B. D., Gopy, S. K., Hurry, G., & Gopaul, T. T. (2013). A study on smart home control system through speech. International Journal of Computer Applications, 69(19).