ResearchGate

Using Edge Computing framework with the Internet of Things for Intelligent Vertical Gardening

Conference Paper · January 2023

DOI: 10.1109/ICAISC56366.2023.10085507

4 authors:


Abhimanyu Bhowmik
Université de Toulon


Madhushree Sannigrahi
Université de Toulon


Pushan Kumar Dutta
Amity University


Saubhik Bandyopadhyay
AMITY UNIVERSITY KOLKATA

Using Edge Computing framework with the Internet of Things for Intelligent Vertical Gardening

Abhimanyu Bhowmik
Department of Artificial Intelligence
Amity University Kolkata
Kolkata, India
Email: abhimanyu.bhowmik@student.amity.edu

Madhushree Sannigrahi
Department of Artificial Intelligence
Amity University Kolkata
Kolkata, India
Email: madhushree.sannigrahi@student.amity.edu

Pushan Kumar Dutta
Department of Computer Science and Engineering
Amity University Kolkata
Kolkata, India
Email: pkdutta@kol.amity.edu

Saubhik Bandyopadhyay
Department of Computer Science and Engineering
Amity University Kolkata
Kolkata, India
Email: sbandyopadhyay@kol.amity.edu

2023 1st International Conference on Advanced Innovations in Smart Cities (ICAISC) | 978-1-6654-7275-3/23/$31.00 ©2023 IEEE | DOI: 10.1109/ICAISC56366.2023.10085507

***Abstract*—The semantic sensor node interprets sensor data from the physical devices that make observations using Semantic Web technology and reasoning. One example is the use of conceptual frameworks in automated gardening systems by collecting plant health characteristics and pest resolution models and optimum temperature control models on a regular basis and passing it to a gardener or a caretaker in a flat making it feasible to monitor plant health status from remote locations. At regular intervals, the Bolt IoT platform collects data on the availability of sunlight and soil moisture content for the plants. After processing and validating data with Integromat (cloud-based logic design), an SMS is delivered to our smartphone via Twilio (cloud communication platform), and the user performs the necessary actions depending on the data. This smart horticulture system will give the user ease and comfort even when they are not physically there, allowing people to better care for our garden.**

***Index Terms*—Automated Gardening, Smart Buildings, AI/ML algorithms, Building Automation, Edge Computing**

I. Introduction

Indoor gardening is the practice of growing plants indoors as part of horticulture to aid in relaxation and stress reduction. Most individuals in today's urbanised world lack the resources and available space to maintain a sizable outside garden. Indoor gardening might be useful in this situation. Growing plants indoors, such as in homes or workplaces, with or without direct sunshine, is known as indoor gardening. These green areas are useful for creating a tranquil environment, boosting productivity, and being aesthetically beautiful. This type of gardening is becoming increasingly popular amongst people due to its cost-effectiveness, the relatively small space required and the fact that it can be done all year round. This paper proposes an analytical approach for automating indoor gardening and management for small and large-scale applications using the Internet of Things (IoT) and artificial intelligence (AI), as shown in Figure 1. In fact, utilising machine learning (ML) algorithms creatively to optimise the performance of building automation systems can result in energy savings and strike a balance between occupant comfort and energy usage.

A. Key Contributions:

The major contributions of smart gardening include:

1) Proposed a combination of frameworks for smart gardening using IoT and edge computing technology with minimal human intervention.
2) In proposed methodology plants are watered only when necessary and accurate cut-off of water without any manual checking.
3) Reduced runoff of water and nutrients with wile Monitoring soil health properties like pH level and NPK (nitrogen (N), phosphorus (P) and potassium (K)) level, which impacts the nutrient availability for the plants, thus keeping them healthy.
4) Maintaining the amount of plant-available macronutrients in the soil.

The document is further sectioned into the subsequent segments: Section II discusses the Related Works whereas Section III proposes the Smart Solution and Section III discusses the Alternative traditional ML Algorithms. Section IV concludes the paper with Conclusion and Future Works.

II. Related Works

The internet of things (IoT) is widely used in modern society to promote the notion of smart apps, which allow users to control remote items from a distance. However, in the majority of recent studies, the connection and processing of an enormous number of devices have emerged as a key issue. In order to address this issue and maintain standardised and compatible home automation solutions, numerous publications have incorporated the ideas of edge computing. Edge computing refers to a distributed computing model that relocates processing and data storage close to the data sources.

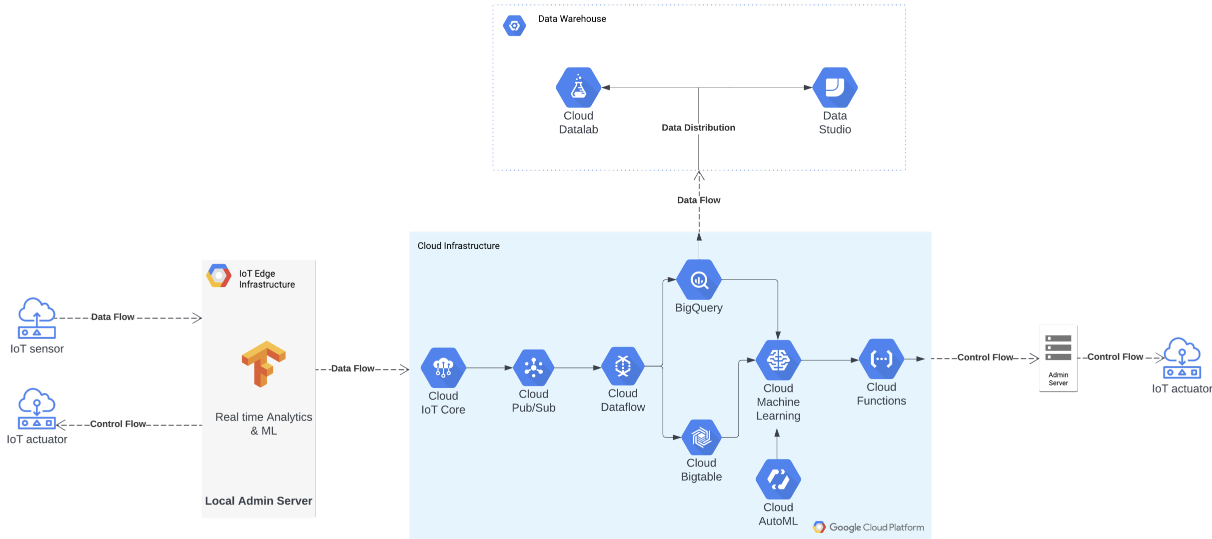

Fig. 1. The Primary Blueprint of the Overall Autonomous Gardening System

Chakraborty et al. presented a smart house design, prototype, and application in their research work to position the prototype as a compact and secure answer for developing smart homes. They made use of the ideas behind virtual IoT devices (VID), edge computing, and the internet of things (IoT) [1]. Similar to this, Saad et al. established Long Short Term (LSTM) based mechanism with edge servers housed in the gateway in another study on Smart Gardening System [2]. End nodes gather data from the environment and communicate it to the gateway using LoRaWAN (Long range Low power Wide Area Network) protocol.

Resource management has become even more difficult to take into account in the edge and fog scenarios as a result of resource shortages, dynamic, heterogeneity and diversified workloads, and the unpredictable nature of fog/edge computing environments. Recently, technologies based on artificial intelligence (AI) and machine learning (ML) have been used to address this issue. The most promising AI/ML techniques for these kinds of issues seem to be those that can make sequential judgements [3]. Several deep learning(DL) concepts like Artificial Neural Networks(ANN) [4], Backpropagation [5], Convolutional Neural Networks(CNN) [6], Computer Vision(CV) [7], and Recurrent Neural Network(RNN) [8] has been implemented in multiple research projects to optimise the energy use in the maintenance of wireless networks among edge servers and automate the processing of the sensors and actuators.

III. Proposed Smart Solution

Components like automatic irrigation systems, intelligent lighting, pest control, and many more can be used to create a smart gardening system. The IoT device's proposed architecture is depicted in Fig. 1. The Bolt IoT Wi-Fi module's job is to gather and send the data to the cloud in this case. Additionally, Integromat logic receives the data. For the purpose of monitoring light intensity and soil moisture during a running scenario in Integromat logic, Bolt receives the read data both in digital and analogue form through the Bolt IoT App. The three sets of variable kits/tools are needed to set the current and operational times in the scenario. This makes it possible to compare different soil moisture levels and sunlight availability in plantation areas. The system for gardening needs to run automatically with little to no human involvement. We suggest local and cloud-phase computing as our solutions. The process begins with sensors (such as temperature, humidity, pH, and other types) that are put in tiny plots of land with the same kind or variety of plants. The gathered data is transferred to a local admin server for basic processing (Edge Computing), after which it is transmitted to a primary server (Local Cloud) or to a traditional cloud platform (AWS, Azure, or GCP), where it is further analysed and machine learning and deep learning models are deployed. The results that have been processed return to the admin server so that the actuators may process the commands. The plant data is needed to create an automated indoor garden.

Pre-requisites

The building or area must have WiFi access and a reliable Heating, ventilation, and air conditioning (HVAC) system. Every sensor and actuator is wireless and uses WiFi to communicate.

The Admin must update the following information:

- Pot number/location
- Plantation date
- Species details
- Condition of the plant when planted (seed, small sprout, full-grown plant)

A cloud database houses all of this information. The entire

TABLE I
ALGORITHMS FOR INTEGRATION OF DATA WITH IOT SENSORS

Algorithms	Requirement	Advantages	References
Partial Least Squares and other regression	Sensors (IoT hardware)	Increased efficiency, increased feasibility	Prokhorov et al. [9], Choudhary et al. [10]
ANN based control system	IoT Sensors	Automation	Umair and Usman [11]
Fuzzy Logic	WSN, Zigbee	Optimization	Al-Ali et al. [12]
ANN, Back-propogation, Fuzzy Logic	IoT Wireless Sensors	Optimization of water resources	Karasekreter et al. [13], Anand et al. [14]

gardening system is separated into several clusters based on species and growth stage using this information. These clusters each contain a number of sensors and actuators. According to the plants' and clusters' natural environment, efforts are made to maintain the optimal climate, light, and humidity conditions. An open source, cloud-based IoT module with ESP8266-12S chips on board is called the Bolt Wi-Fi module [15].

With the help of Bolt IoT applications, it is simple to connect to our smartphones. A 5V DC source is used to power this board through a USB connection. GPIO (general-purpose input/output) [16] capabilities are available on this module. ESP8266-12s are the foundation for a number of other IoT module types. The Bolt IoT development module does, however, feature the Bolt cloud, which is accessible through the Bolt app on our smartphone, which is further connected to the module by Wi-Fi internet.

A. Smart Irrigation

Tensiometric soil moisture sensors (Tensiometers are soil moisture sensors that measure tension between soil particles and water molecules) are used to detect soil moisture. Comparing this moisture level, plant size, last watering timestamp, the plant species' ideal growth condition and based on previous data, a cloud-based ML/DL algorithm will predict the amount of water needed by the plant. Based on this prediction, the actuator which is responsible for irrigation will water the plants accordingly. Figure 2 shows the smart irrigation architecture.

A powerful cloud-based communication platform is Twilio. It provides software developers with the ability to create applications that can send and receive SMS or phone calls using the web service Application programming interfaces (APIs) [17]. Integromat connects the necessary applications, services, and cloud with the right sensors and modules to build scenarios for data collection using logic. Therefore, we must create a logical scenario that, when the request is made, will run, gather the data, and then Integromat will analyse it and do the necessary action. The device ID for Bolt, key for API, authentication token number, SSID, and sender's number to access Twilio service must now be supplied in order to activate the Bolt IoT service. Some ML algorithms which can be used for automated irrigation are in table I.

B. Growth-friendly Smart Lights

Custom LED(Light Emitting Diode) panels known as "growth lights" replicate the sun and offer the full spectrum of light that plants require to thrive. In comparison to growing with fluorescent or incandescent lights, LED lights are the most effective and customer-friendly approach to growing plants in indoor areas since they deliver low energy use, low heat, and colour optimization for development. A typical small-scale private garden takes 30 to 40 W to power the lights. Each cluster contains photoelectric devices or photo sensors that measure the time and intensity of light.

Using AI/ML algorithms, we compare this data to the natural environment or the ideal growth circumstances for the plants to determine the perfect light intensity, colour, and duration. The actuators receive this data, and according to the plant's development stage and the time of year, modifications are made to the lighting settings in clusters. Plant Growth Determines the Color of Light The 400–520 nm range of violet–blue light promotes the uptake of chlorophyll, photosynthesis, and growth. The spectrum of red light between 610 and 720 nm encourages blooming and budding.

C. Nutrients control

The pH and NPK sensors are used to measure the soil's pH and its levels of nitrogen, phosphorus, and potassium. AI/ML algorithms activate the actuators to maintain the ideal nutrient balance for plant development based on the plant species and the collected data. The hydroponic nutrient additives will be available to the actuators, and they may be supplied to the soil based on the plant's needs, species, and stage of growth. Plant growth can be divided into three stages, each with its own set of nutrient requirements. For instance:

1) Sprouts: This nutrient is intended for early development and strengthens the leaves and stems of plants. It contains macronutrients including Fe, N, Ca, and K.

2) Thrive: The nutrients that are essential for plant development and contain all the micronutrients are Mg, K, P, B, Cu, Zn, Na, and other elements that plants require to develop their stems, leaves, flowers, and fruits.

3) Blossom: This nutrient improves a plant's innate capacity for growth and fruit production. Only when plants are prepared to produce blooms and fruit do they need to utilise this nutrient. It has elements like Fe, N, Ca, and K.

D. Smart Temperature Control

Temperatures that are too high or too low hinder photosynthesis, which is how plants make food for themselves and fuel their development. Implementing a suitable HVAC system and having sufficient heating and cooling capacity is necessary for managing cluster-specific temperatures in accordance with the species' optimal growing conditions. The most crucial temperature measurement for development is the average temperature during a 24-hour period or daily temperature.

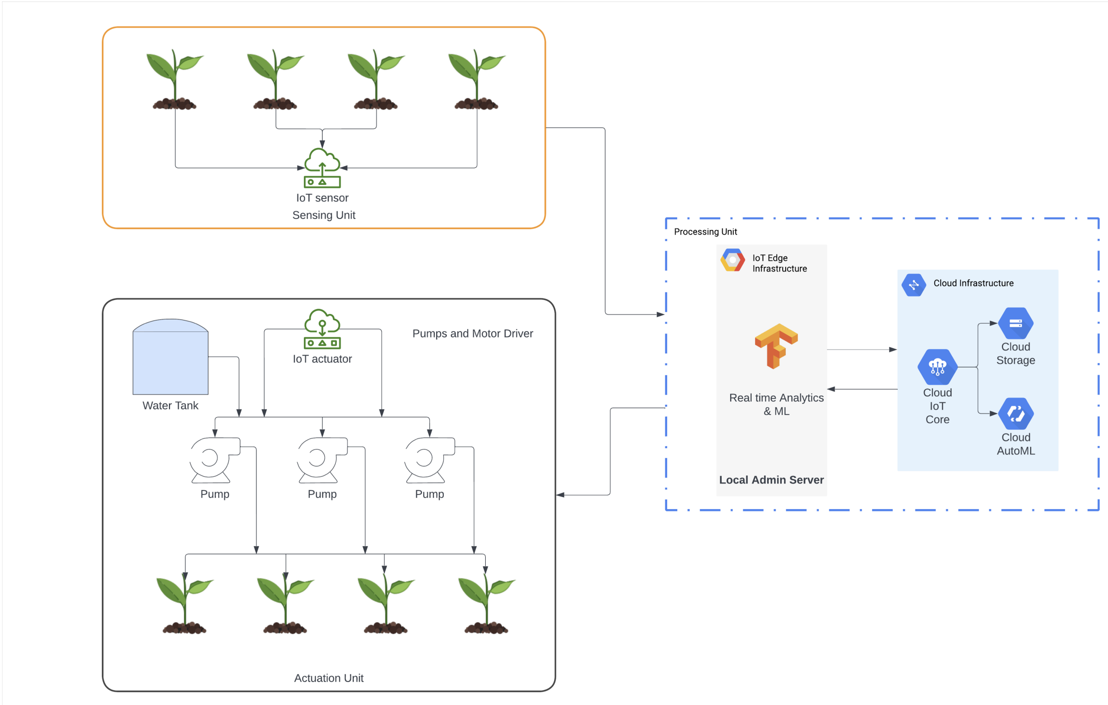

Fig. 2. Smart Irrigation Architecture

TABLE II
ALGORITHMS FOR PLANT GROWTH PREDICTION.

Algorithms	Requirement	Advantages	References
Convolutional LSTM	Camera, LIDAR	Plant growth prediction	Sakurai et al. [18]
DL- RNN, LSTM	Temperature, Humidity and Photo sensor	Predict plant growth	Pearson et al. [19], Chen et al. [8]

TABLE III
ALGORITHMS FOR PEST MONITORING

Algorithms	Requirement	Advantages	References
CNN, CV	Camera, LIDAR	Plant disease and pest detection	Lin et al. [20], Kök et al. [6]
ML and CNN based model	Camera, IoT Sensors	PInsect Pest classification and detection	Kasinathan et al. [7]

E. Plant Health Monitor

Sensors detect and log information on the health of the plants, such as how many plants are thriving in each cluster, which clusters are growing at extremely low or high rates, how quickly various clusters germinate, the rate of disease detection and monitoring, etc. Additionally, it uses a camera to record the growth and stores environmental information (humidity, temperature, light sensors). In nurseries and greenhouses, this is essential. For monitoring plant growth, the ML algorithms may be taken into account provided in table II.

F. Smart Pest Control

Webcam and LIDAR(Light Detection and Ranging) pictures can identify the health of the leaf and stem as well as the existence of any pests in clusters in addition to plant health monitors. The AI/ML model will identify the issue in situations of illness and insect invasion, notify the system administrator, and provide appropriate solutions. With administrator assistance, the actuators will provide the required insecticide or pesticide dosages to the plants or clusters. Figure 3 depicts environmental data (sensor readings for light, temperature, and humidity). In nurseries and greenhouses, this is vital. As stated in Table III, the following machine learning methods can be taken into consideration for monitoring pests and diseases.

By using these techniques, we may create a garden that is both healthy and completely functioning. The technology may be used outside in big regions. Human connection is drastically decreased when it comes to the efficient upkeep of sizable indoor and outdoor gardens in business settings like offices, malls, and so forth, as well as in private homes and nurseries.

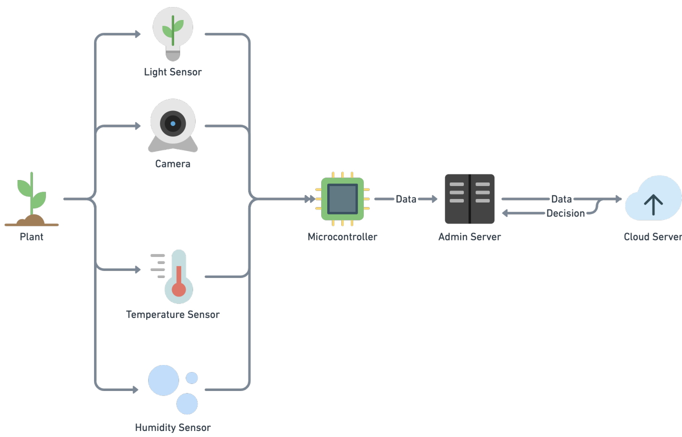

Fig. 3. Plant Health Monitor System

IV. Traditional ML Algorithms Alternative

The above-mentioned traditional algorithms have already been tested and implemented in various studies and similar research areas and have a high accuracy index. We can use these algorithms in the cloud to predict useful information about specific use cases, or we can use Cloud AutoML and improve on it as needed. We can pick the right auto-ML model as per the datasets, such as a structured data classifier or regressor for a tabular dataset, an image data classifier for an image dataset, and so on. AutoML engines are included with major cloud providers' cloud solutions (AWS, GCP, and Azure) and can be easily implemented and improved. Using AutoML we can generate various Machine Learning and Deep Learning models with some pre-tuned hyper-parameters among which the most efficient and highest accuracy model will be chosen and implemented on the cloud for further online training on newer emerging data from the installed sensors as shown in Figure 3.

The exact administration of agrochemicals, fertilisers, and water will be made possible by monitoring plant health to enhance output. To monitor the garden, a whole system of sensors, a Bolt module, and software has been developed. However, we built up the entire system at a modest scale by using a flower pot for testing purposes. In order to set up an alarm through text message (SMS) using Twilio, we have developed a functioning sequence in Integromat. An alarm system will be started and an SMS will be sent to the user instructing them to take the necessary action as soon as the light availability or moisture content falls below the limit value. Sending out a reminder to water the plant. A Sensor for Soil Moisturizer Module. The sensor output value is in percentages. During the testing, the soil's dryness limit is kept at 35%. As a result, when the soil moisture content is less than 35%, the sensor output is low; otherwise, it is high for the other value. This constitutes digital data on pin 0 of the Bolt IoT module. During the execution of the scenario in Integromat logic, Bolt receives read requests for moisture content data in both digital and analogue formats via the Bolt IoT App. For a satisfactory condition, the user receives an SMS as a plantation health alert.

V. Conclusion & Future Works

The produced project could assess the essential data in real time and then communicate the results to the customer via mobile applications so they could take the appropriate action. This technology is very simple to utilise and put into practice. The user may examine the availability of moisture and sunshine in real-time using the Bolt IoT app on their smartphone in addition to the alarms. This gadget is moderately priced and features a number of sensors, including a light sensor and a soil moisture sensor.

In the future, raw sensor observations might be converted to RDF(Resource Description Framework) format and connected to other datasets on the Linked Open Data (LOD) cloud to provide linked sensor data. More focus can be given to Federated Learning since it improves user privacy and training of the model [10]. Moreover, handling the huge amount of generated data (big data) can be done in a better way using the time-series approach [21]. Additionally, the introduction of Blockchain in the system for an overall robust security [22].

References

[1] T. Chakraborty and S. K. Datta, "Home automation using edge computing and internet of things," in *2017 IEEE International Symposium on Consumer Electronics (ISCE)*, 2017, pp. 47–49.

[2] M. M. Saad, M. T. R. Khan, M. A. Tariq, and D. Kim, "Lstm enabled artificial intelligent smart gardening system," in *Proceedings of the International Conference on Research in Adaptive and Convergent Systems*, 2020, pp. 136–141.

[3] S. Iftikhar, S. S. Gill, C. Song, M. Xu, M. S. Aslanpour, A. N. Toosi, J. Du, H. Wu, S. Ghosh, D. Chowdhury *et al.*, "Ai-based fog and edge computing: A systematic review, taxonomy and future directions," *Internet of Things*, p. 100674, 2022.

[4] S. Choudhary, V. Gaurav, A. Singh, and S. Agarwal, "Autonomous crop irrigation system using artificial intelligence," *Int. J. Eng. Adv. Technol*, vol. 8, no. 5, pp. 46–51, 2019.

[5] N. Karasekreter, M. A. Şahman, F. Başçiftçi, and U. Fidan, "Pso-based clustering for the optimization of energy consumption in wireless sensor network," *Emerging Materials Research*, vol. 9, no. 3, pp. 776–783, 2020.

[6] İ. Kök and S. Özdemir, "Deepmdp: A novel deep-learning-based missing data prediction protocol for iot," *IEEE Internet of Things Journal*, vol. 8, no. 1, pp. 232–243, 2020.

[7] T. Kasinathan, D. Singaraju, and S. R. Uyyala, "Insect classification and detection in field crops using modern machine learning techniques," *Information Processing in Agriculture*, vol. 8, no. 3, pp. 446–457, 2021.

[8] G. Chen, J. Wu, W. Yang, A. K. Bashir, G. Li, and M. Hammoudeh, "Leveraging graph convolutional-lstm for energy-efficient caching in blockchain-based green iot," *IEEE Transactions on Green Communications and Networking*, vol. 5, no. 3, pp. 1154–1164, 2021.

[9] S. Prokhorov, Y. Krivoshein, and A. Shilin, "Automatic control of hot water supply system on solar collectors," in *2019 International Multi-Conference on Industrial Engineering and Modern Technologies (FarEastCon)*. IEEE, 2019, pp. 1–6.

[10] D. Chowdhury, S. Banerjee, M. Sannigrahi, A. Chakraborty, A. Das, A. Dey, and A. D. Dwivedi, "Federated learning based covid-19 detection," *Expert Systems*, p. e13173, 2022.

[11] S. M. Umair and R. Usman, "Automation of irrigation system using ann-based controller," *International Journal of Electrical & Computer Sciences IJECS-IJENS*, vol. 10, no. 02, pp. 41–47, 2010.

[12] A.-R. Al-Ali, M. Qasaimeh, M. Al-Mardini, S. Radder, and I. A. Zualkernan, "Zigbee-based irrigation system for home gardens," in *2015 International Conference on Communications, Signal Processing, and their Applications (ICCSPA'15)*. IEEE, 2015, pp. 1–5.

[13] N. Karasekreter, F. Başçiftçi, and U. Fidan, "A new suggestion for an irrigation schedule with an artificial neural network," *Journal of Experimental & Theoretical Artificial Intelligence*, vol. 25, no. 1, pp. 93–104, 2013.

[14] K. Anand, C. Jayakumar, M. Muthu, and S. Amirneni, "Automatic drip irrigation system using fuzzy logic and mobile technology," in *2015 IEEE technological innovation in ict for agriculture and rural development (TIAR)*. IEEE, 2015, pp. 54–58.

[15] A. A. Aldair, A. T. Rashid, and M. Mokayef, "Design and implementation of intelligent control system for egg incubator based on iot technology," in *2018 4th International Conference on Electrical, Electronics and System Engineering (ICEESE)*. IEEE, 2018, pp. 49–54.

[16] R. K. Kodali and A. Sahu, "An iot based soil moisture monitoring on losant platform," in *2016 2nd International Conference on Contemporary Computing and Informatics (IC3I)*. IEEE, 2016, pp. 764–768.

[17] Communication apis for sms, voice, video and authentication. (n.d.). retrieved august 27, 2021. [Online]. Available: https://www.twilio.com/

[18] S. Sakurai, H. Uchiyama, A. Shimada, and R.-i. Taniguchi, "Plant growth prediction using convolutional lstm." in *VISIGRAPP (5: VISAPP)*, 2019, pp. 105–113.

[19] B. Alhnaity, S. Pearson, G. Leontidis, and S. Kollias, "Using deep learning to predict plant growth and yield in greenhouse environments," in *International Symposium on Advanced Technologies and Management for Innovative Greenhouses: GreenSys2019 1296*, 2019, pp. 425–432.

[20] J. Liu and X. Wang, "Plant diseases and pests detection based on deep learning: a review," *Plant Methods*, vol. 17, no. 1, pp. 1–18, 2021.

[21] A. Bhowmik, M. Sannigrahi, P. Guha, D. Chowdhury, and S. S. Gill, "Dynamite: Dynamic aggregation of mutually-connected points based clustering algorithm for time series data," *Internet Technology Letters*, p. e395, 2022.

[22] M. Golec, D. Chowdhury, S. Jaglan, S. S. Gill, and S. Uhlig, "Aiblock: Blockchain based lightweight framework for serverless computing using ai," in *2022 22nd IEEE International Symposium on Cluster, Cloud and Internet Computing (CCGrid)*. IEEE, 2022, pp. 886–892.