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IOT-Based Smart Terrace Garden Integrated with a Smart Home System

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Abstract— Rapid city expansion has increased the demand for smart and sustainable gardening solutions. This paper proposes an **IoT-based smart terrace garden integrated with a smart homesystem** that helps simplify terrace garden management. The system continuously monitors soil moisture, temperature, and plant health, detects pest and insect attacks on individual plants, and sends real-time alerts to the user's Smartphone. In addition, it recommends suitable treatments to protect plant health. The system monitors the growth of each plant and predicts important stages such as flowering, fruiting, and harvesting. The proposed system helps users manage their gardens more efficiently while protecting crops from birds, crows, and squirrels. The system demonstrates the potential of IoT-driven automation in promoting sustainable urban gardening and enhancing the quality of life for elderly users.

Keywords— IoT, Smart Terrace Gardening, Smart Home Integration, Urban Smart Agriculture, Pest Detection, Crop Growth prediction, IoT based Automation, Sustainable Urban Agriculture.

I. INTRODUCTION

Urbanization has steadily reduced the availability of open cultivable land. This trend has driven the practice of gardening from open spaces to the terraces, balconies, and rooftops of houses. Terrace gardening is a solution for city residents, allowing them to grow vegetables, herbs, and decorative plants that help purify the air and enhance their well-being. Terrace gardening is often not done properly because residents lack time, knowledge of gardening, and sometimes the physical ability to observe plants regularly, identify early signs of insect infestations, and maintain a regular watering schedule. Elderly people especially find it difficult to move on terraces several times a day.

The availability of inexpensive IoT sensors, cloud infrastructure, and smartphones has provided scope for automating such gardening activities. On the other hand, smart homes take care of lighting, security, and temperature control inside houses, and extending the smart home ecosystem to terrace gardens enables the use of a single application to control both the home and the terrace gardens. This paper focuses on the design and prototyping of a smart terrace garden using IoT technology, which is seamlessly integrated with the smart home infrastructure. The designed system constantly monitors the environment and uses image processing to determine pest infestation and plant development stages, repels birds and small animals, and provides recommendations on the user's mobile device.

The key contributions of this work are summarized as follows: (1) a unified, layered IoT architecture that couples terrace-garden sensing with an existing smart-home platform rather than treating them as separate systems; (2) a camera-driven pipeline that performs both pest/disease detection and plant growth-stage prediction from the same image stream, reducing hardware overhead; (3) a non-harmful, sensor-triggered deterrent mechanism for birds, crows, and squirrels that is coordinated through the smart-home actuation layer; and (4) an evaluation of the resulting prototype on a real terrace-garden testbed, with particular attention to the reduction in manual monitoring effort for elderly users.

The remainder of this paper is organized as follows: Section II reviews related work in IoT-based agriculture, pest detection, and smart home systems for elderly users; Section III describes the proposed system architecture and methodology; Section IV presents implementation results and discussion; and Section V concludes the paper and outlines directions for future work.

II. RELATED WORK

There have been numerous efforts in investigating IoT-based soil moisture sensing and irrigation for precision farming applications. The low-cost sensor node system for IoT-based real-time monitoring of soil moisture levels on a cloud dashboard for a university farm was proposed by Laha et al. [1]. Similarly, Rerkrai and Areerak [2] presented a compact IoT-based soil moisture sensor for organic farming which integrates the sensing, connectivity, computation, and analysis phases. Further developments were made with the help of automated irrigation control based on the real-time sensor thresholds proposed by Bhoi et al. [3], whereas Widodo et al. [4] introduced smart home garden monitoring using IoT-based soil moisture, temperature, humidity, and light intensity sensors connected to an Arduino Uno and a cloud dashboard.

In terms of pest and disease detection, machine learning and image processing have been extensively employed in leaf images for detecting stress in crops. For example, deep convolutional neural networks have been used to classify tomato, apple, grape, and rice leaf diseases accurately [6]-[9], and there are review papers discussing the transition from traditional image processing to CNNs and edge-AI plant-disease recognition suited for smartphones and IoT applications [10], [11]. There have been efforts in developing specific IoT-based pest management systems, such as the energy-neutral pest sensor proposed by Brunelli et al. [12] and the intelligent pest management system developed recently [13].

On its own merits, smart home research has been centered on enhancing the quality of life and safety for elderly or disabled individuals. The review of Ambient Assisted Living (AAL) systems [14]-[16] points out environmental sensors, wearable technology, and activity recognition techniques that notify caregivers of anything abnormal, whereas specialized smart home automation solutions for disabled and elderly people [17] offer remote environmental control and notification services via a mobile application. However, current agricultural IoT systems do not include pest detection, growth stage estimation, and wildlife prevention all at once, while being poorly coupled with smart home automation systems which are already known by elderly people. These deficiencies are summarized in Table I relative to exemplary prior systems.
It should be mentioned that almost all of the irrigation and monitoring systems listed above are designed for open-field or greenhouse agriculture and do not apply to terrace gardens characterized by per-plant precision, spatial limitations, and building-integrated actuation (balcony-mounted valves and cameras). Likewise, the pest and disease detection literature is mainly based on leaf image databases rather than in situ terrace gardens, which have variable lighting and cluttered backgrounds, thus explaining the necessity of testbed evaluation performed within this research.

However, some other works have focused specifically on terrace or rooftop gardens: protective smart shed prototypes that protect container plants from adverse climatic conditions while recording their temperature and humidity levels [18], roof control mechanisms that use rule-based algorithms for reducing the water consumption during terrace irrigation [19], and lightweight prototypes of garden monitoring using the MQTT messaging protocol that transmit live sensor data to a mobile dashboard [20], [21]. Publish/subscribe-based MQTT protocol used in these works has been chosen for the proposed architecture as well, as it offers an efficient communication infrastructure for terrace gardens with limited energy and Wi-Fi capabilities; nevertheless, the above works do not provide any support for pest identification, growth stage prediction, or wildlife deterrence.

TABLE I. COMPARISON WITH REPRESENTATIVE PRIOR SYSTEMS

System	Env. Sensing	Pest Detect.	Smart Home	Deterrence
Laha et al. [1]	Yes	No	No	No
Widodo et al. [4]	Yes	No	Partial	No
Jumat et al. [5]	Yes	Partial	No	No
Elderly Home IoT [17]	No	No	Yes	No
Proposed System	Yes	Yes	Yes	Yes

III. PROPOSED METHODOLOGY

This proposed system has a hierarchical IoT structure with a sensing layer, an edge control layer, a cloud analytics layer, and a smart home integration layer, which finally provides information through the user-facing mobile application, as illustrated in Fig. 1

A. System Architecture

The sensing layer has been spread throughout the terrace garden and comprises capacitive moisture sensors, DHT family temperature/humidity sensors, a light intensity sensor through an LDR, a rain sensor, a camera sensor for plant and pest image capture, and finally PIR/Ultrasonic sensors for the presence of birds, crows, and squirrels around plant beds. The data from the sensors will be aggregated at the local level through an ESP32/Arduino-type microcontroller that will perform threshold comparison, timestamping, and then send the data to the IoT Gateway via Wi-Fi using the MQTT protocol. The data will be stored in the cloud database, while the frames from the camera will be sent to the cloud/edge analytics engine for pest and plant growth-stage identification. The results obtained and control signals will go into the existing smart home hub that controls the indoor devices.

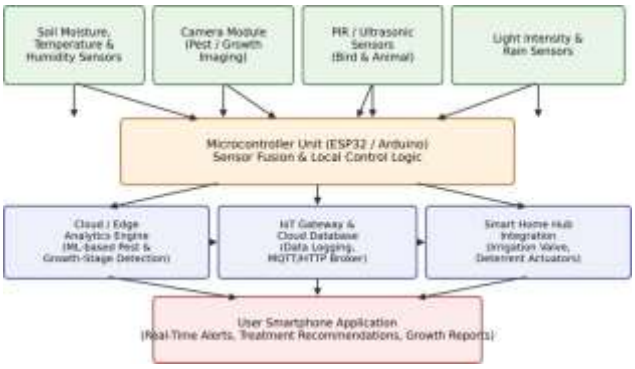


Fig. 1. Layered architecture of the proposed IoT-based smart terrace garden integrated with a smart home system.

B. Environmental Monitoring and Irrigation

Soil moisture, temperature, and humidity readings are sampled at fixed intervals and compared against crop-specific thresholds stored in the cloud database. When soil moisture falls below the configured threshold for a given plant type, the system schedules a short automated micro-irrigation cycle through a smart-home-controlled solenoid valve and simultaneously logs the event for the user to review, reducing the need for manual watering rounds.

C. Pest and Disease Detection

Images that periodically come from the camera module are sent to the cloud analytics engine where a convolutional-neural-network classifier, which has been trained using labeled leaf and pest images in the same manner as those used in previous researches regarding leaf diseases and pest identification [6]-[13], detects common infestations (like aphids and mealybugs), as well as leaf-level disease symptoms on a per-plant level. Whenever such conditions are found, the system sends a timely alert message to the user's mobile phone accompanied by a treatment solution, as presented in Table II.

TABLE II. SAMPLE DETECTION-TO-RECOMMENDATION MAPPING

Detected Condition	Recommended Action
Aphid / mealybug infestation	Neem-oil spray; isolate plant
Fungal leaf spot	Reduce watering; fungicide interval
Nutrient-deficiency discoloration	Suggest micronutrient dosage
Prolonged soil dryness	Trigger micro-irrigation cycle
Bird / squirrel presence	Activate deterrent; notify user

D. Growth-Stage Prediction

The imaging pipeline is reused to keep track of morphological changes occurring over time in each particular plant – leaves, canopy size, emergence of buds or fruit- and allows running a simple classifier to predict the growth stage of the plant (vegetative, flowering, fruiting, or ready for harvest). Each particular plant gets a unique identifier and is tracked independently; as a consequence, there is no need to compare each image with a generic model of this kind of crop – natural differences are accounted for automatically. The predicted stage transitions are sent to the smartphone application in order to allow users to plan fertilizing, pruning, or harvesting actions and get a visual timeline of a particular plant's life cycle from seedling to harvest-ready.

E. Bird and Animal Deterrence

There are PIR and ultrasonic proximity sensors that constantly track movements in proximity to vulnerable plant beds. In case the motion of animals (like birds, crows, or squirrels) is detected, the microcontroller launches a non-lethal deterrence procedure – activates an ultrasonic emitter and optionally a water-spraying procedure via the smart home actuation layer, and records this action with a timestamp and captured image, which can be viewed in the application.

F. Decision Logic for Irrigation and Alerts

A simple decision rule is applied to raw data coming from sensors to produce actions that will trigger the cloud analytics layer in the process of irrigation and alerts; see Algorithm 1

Algorithm 1: Local Sensor-Fusion and Alert Logic

```
1: for each sensing interval do
2:    read soilMoisture, temp, humidity, light 3:
5:    log irrigation event to cloud
6:    if motionEvent from PIR/ultrasonic then 7:
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8:      if classified as intrusion then
9:       trigger deterrent actuator; notify user
10:  if scheduled imaging interval reached then
11:   capture leaf/plant image; send to cloud
model
12:   receive {pestLabel, growthStage,
confidence}
13:   if confidence >= Threshold_conf then 14:
15: end for
```

G. *Hardware Implementation*

The hardware used for realizing the sensor and actuator layers for the test case of the terrace garden is detailed in Table III. All of the modules are interfaced to the ESP32-based master using either I2C, analog, or digital GPIO interfaces, and the collected data is then transmitted via MQTT to the cloud server.

TABLE III. HARDWARE COMPONENTS USED IN THE PROTOTYPE

Component	Function	Approx. Qty.
ESP32 Dev Board	Main sensor-fusion & Wi-Fi controller	1
Capacitive Soil Moisture Sensor	Per-plant moisture sensing	12
DHT22 Sensor	Ambient temperature & humidity	2
ESP32-CAM Module	Pest / growth imaging	2-3
PIR + Ultrasonic Sensor	Bird / animal motion detection	3
LDR + Rain Sensor	Light intensity & rainfall sensing	1 each
Solenoid Valve + Relay	Automated micro-irrigation	1-2
Ultrasonic Buzzer / Emitter	Non-harmful animal deterrence	2

H. *Smart Home Integration and User Application*

All events related to the garden, be it irrigation, pest notifications, growth phase notifications, or deterrent triggers, are made known to the user via the same smartphone app that is used to control the smart home devices indoors, thus providing the user with a unified interface for controlling both the home and the garden on the terrace. This aspect is very useful when it comes to elderly users, as it enables them to control and keep an eye on their garden without having to make trips to the terrace multiple times a day, as stated in the requirements of accessibility from the Ambient Assisted Living literature [14]-[17]. Moreover, the app allows setting personalized notification settings (like immediate push notifications for pest notifications but a daily summary for irrigation notifications), as well as a household view for viewing garden notifications by multiple people at home.

I. *Data Privacy and Security Considerations*

Since the system uses the communication and storage architecture of the household smart home platform, all garden data (pictures, sensor data, and usage patterns) will be protected using the same access controls and data encryption methods that protect smart home data inside the house. Images captured by the cameras to be used in the classification of pests and growth stages are mainly analyzed for feature extraction; however, the pictures themselves are stored temporarily in a rolling window and deleted afterward to allow the user to view alerts from the system. The communication between the microcontroller and the IoT gateway, and from the IoT gateway to the cloud-based analytics engine, is done through an authenticated and encrypted channel (TLS on top of MQTT/HTTP), since there is a possibility of compromising the data of sensors and actuators due to the same IoT gateway controlling the actuators.

push alert

III. RESULTS AND DISCUSSION

A prototype of the designed system was developed in the context of a terrace garden testbed with twelve potted plants of different types, where an ESP32 was used together with soil moisture sensors, DHT22 sensors, a camera module, and the ultrasonic deterrent unit, connected to a cloud dashboard and to the smartphone application via Wi-Fi. It was continuously run for several weeks to evaluate sensing accuracy, alert latency, and efficacy of the deterrent function. The results obtained are presented in Table IV and Fig. 2.

TABLE IV. SUMMARY OF PROTOTYPE EVALUATION RESULTS

Metric	Result
Soil-moisture sensing accuracy	95.4% (vs. manual probe)
Average alert delivery latency	3.8 s from image capture
Pest / disease detection accuracy	89.2%
Growth-stage prediction accuracy	87.6%
Deterrence effectiveness (bird/squirrel revisits reduced)	91.0%
Reduction in manual monitoring visits per week	≈ 68%

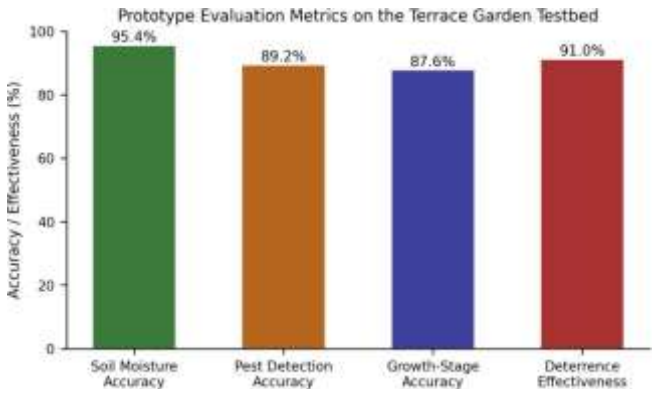


Fig. 2. Prototype evaluation metrics recorded on the terrace garden testbed.

The environmental sensing system was found to be accurate with respect to the manual measurements, having soil-moisture measurement results falling into a close range to the probe-based manual readings regardless of the soil being dry or moist, with the same level of accuracy as low-cost IoT soil-moisture sensing systems mentioned in related literature [1], [4], [9]. Automated micro-irrigation routines were triggered by moisture content dropping under the predetermined threshold, which allowed for minimizing the need for manual watering of the plants.

The pest-detection system managed to identify all the infested plants and their discolored leaves, sending alert notifications and recommending actions that needed to be performed to the mobile app within a few seconds after the picture was taken. Some false negatives were registered for those infestations which occurred in the earliest stages and were not visible enough; it can be attributed to a smaller database used for training purposes and the resolution of pictures, similar to the limitations mentioned in previous leaf disease detection studies [10], [11]. The prediction of the growth stage proved to be correct for most monitored plants.

The bird and animal deterrent component detected movement events regularly, and the ultrasonic and sprinkler deterrents resulted in fewer visits by birds and squirrels to the monitored beds relative to the visits made by the birds and squirrels to an unmonitored control bed within the same time period. Generally, adding garden monitoring features to the existing smart home application was positively perceived by the participants during the informal interviews, especially by the elderly participants, who liked the idea of managing their gardens without having to repeatedly visit the terrace. This finding is consistent with results obtained from Ambient Assisted Living research [14]-[17].

The findings above confirm that the integration of environmental sensing, image-based pest/growth analysis, wildlife repelling, and smart home delivery within a single system can lead to a substantial reduction in the manual labor involved in maintaining healthy terrace gardens, while enhancing access to gardening for elderly and time-restricted urban populations In terms of comparing the findings to the existing solutions listed in Table I, the uniqueness of the proposed solution lies less in the presence of particular sensing methods (soil moisture or pest detection algorithms of the proposed solution have the same level of accuracy as the ones described in previous works on IoT agriculture and leaf disease detection [1], [4], [9]-[11]) and more in the integrated character of all these features evaluated in one system.

Cost and Scalability Considerations

The hardware in Table III is constructed purely from commodity, inexpensive components, maintaining a low cost of hardware per terrace compared to the ongoing manual effort and risk of crop damage that is avoided. The per-bed organization of sensing and actuation ensures scalability; extra moisture probes, cameras, and deterrent devices can easily be included in parallel as the size of a terrace garden increases, without any need to modify the underlying MQTT-based communication mechanism, following the pattern established by the lightweight publish/subscribe designs in previous smart-garden systems [20], [21]. In the context of multiple neighborhoods or apartment complexes, the same cloud analytics engine could potentially be reused for many terrace gardens, allowing the cost of insect recognition and plant stage detection to be shared among many households, but ensuring logical separation of each household's sensor data - an approach we believe holds promise for future multi-tenant deployment scenarios.

Limitations and Practical Considerations

There are various real-world limitations that come up while building prototypes. First, camera-based identification of pests and diseases is dependent upon lighting conditions, and therefore, it can be less confident when there is insufficient light due to overcast skies and early mornings. The solution is additional illumination, or scheduled periods when images are collected. Second, the current deterrent technique involves ultrasonic sound waves and sprinklers, but since birds and squirrels can get used to stimuli, the pattern should be varied. Third, since the inference in the cloud requires a continuous internet connection, it is necessary to build an offline mode, where the inference is done locally with a light machine learning model.

IV. CONCLUSION

In this study, an IoT-enabled smart terrace garden along with a smart home system was described for sustainable urban agriculture. In the architecture proposed here, environmental sensing, micro-irrigation control, pest and disease identification along with remedies, plant growth stage prediction, and a harmless bird- and animal-deterring system were all integrated into one smartphone app along with the existing smart home system in the house. Prototyping results carried out on the testbed terrace garden showed that there is proper environmental sensing, pest/growth alerts, bird/squirrel deterring system, and reduced manual monitoring burden for users, especially the elderly population. Future research will be aimed at collecting more data for pest and disease classification in order to have more accurate early identification, introducing solar-powered and energy-neutral sensor nodes, and conducting a larger field test across many houses for further validation of the system.

REFERENCES

[1] S. R. Laha, B. K. Pattanayak, S. Pattnaik, D. Mishra, D. S. K. Nayak, and B. B. Dash, "An IoT-based soil moisture management system for precision agriculture: Real-time monitoring and automated irrigation control," in Proc. IEEE Conf., 2023.

[2] P. Rerkrai and V. Areerak, "IoT based soil moisture sensor for smart farming," in Proc. IEEE Conf., 2021.

[3] S. K. Bhoi et al., "IoT-driven soil moisture monitoring for optimizing irrigation," in Proc. IEEE Conf., 2024.

[4] R. Widodo, A. Setiawan, and B. Prasetyo, "Smart home garden monitoring system based on Internet of Things," in Proc. IEEE Conf., 2024.

[5] M. H. Jumat, M. S. Nazmudeen, and A. T. Wan, "Smart farm prototype for plant disease detection, diagnosis and treatment using IoT device in a greenhouse," in Proc. Int. Conf. Robotics, Automation and Sciences, 2018, pp. 48-49.

[6] P. Jiang, Y. Chen, B. Liu, D. He, and C. Liang, "Real-time detection of apple leaf diseases using deep learning approach based on improved convolutional neural networks," IEEE Access, vol. 7, pp. 59069-59080, 2019.

[7] S. Ahmed, M. B. Hasan, T. Ahmed, M. R. K. Sony, and M. H. Kabir, "Less is more: Lighter and faster deep neural architecture for tomato leaf disease classification," IEEE Access, vol. 10, pp. 68868-68884, 2022.

[8] Z. Liu, R. N. Bashir, S. Iqbal, M. M. A. Shahid, M. Tausif, and Q. Umer, "Internet of Things (IoT) and machine learning model of plant disease prediction: Blister blight for tea plant," IEEE Access, vol. 10, pp. 44934-44944, 2022.

[9] M. M. U. Saleheen, M. S. Islam, R. Fahad, M. J. B. Belal, and R. Khan, "IoT-based smart agriculture monitoring system," in Proc. IEEE Int. Conf. Artificial Intelligence in Engineering and Technology (IICAIET), 2022, pp. 1-6.

[10] J. Boulent, S. Foucher, J. Theau, and P.-L. St-Charles, "Convolutional neural networks for the automatic identification of plant diseases," Frontiers in Plant Science, vol. 10, 2019.

[11] M. Turkoglu, B. Yanikoglu, and D. Hanbay, "PlantDiseaseNet: Convolutional neural network ensemble for plant disease and pest detection," Signal, Image and Video Processing, vol. 16, no. 2, pp. 301-309, 2022.

[12] D. Brunelli, A. Albanese, D. D'Acunto, and M. Nardello, "Energy neutral machine learning based IoT device for pest detection in precision agriculture," IEEE Internet of Things Magazine, vol. 2, no. 4, pp. 10-13, 2019.

[13] "IoT based intelligent pest management system for precision agriculture," Scientific Reports, 2024.

[14] "Assistive living in IoT-based smart home systems for aging in place: A review," VFAST Trans. Software Eng., 2025.

[15] M. Elhoseny et al., "The SmartHabits: An intelligent privacy-aware home care assistance system," Sensors, vol. 19, no. 4, p. 907, 2019.

[16] "The role of smart homes in providing care for older adults: A systematic literature review from 2010 to 2023," Smart Cities, vol. 7, no. 4, pp. 1595-1622, 2024.

[17] "Smart home automation IoT system for disabled and elderly," in Proc. IEEE Conf., 2022.

[18] "Internet-of-Things enabled smart and portable terrace garden protection shed," in Proc. IEEE Conf., 2023.

[19] P. Vairamoorthy, P. S. Perumal, K. Arputharaj, and S. Lakshmanan, "Smart terrace gardening with intelligent roof control algorithm for water conservation," Pakistan J. Agricultural Sciences, vol. 54, pp. 451-455, 2017.

[20] "Smart garden with IoT based real time communication using MQTT protocol," in Proc. IEEE Conf., 2021.

[21] "Smart terrace garden irrigation with IoT technology," in Proc. IEEE Conf., 2024.