JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

IOT AND ML BASED PESTICIDE RESIDUE DETECTION IN FRUITS AND VEGETABLES

[1]K Umamaheswari, [2]Dr U Somalatha
[1]P. G Student, [2]Assistant Professor
[1] Dept. Of ECE, VEMU Institute of Technology, Chittoor, India
[2] Dept. Of ECE, VEMU Institute of Technology, Chittoor, India

***Abstract**:* The increasing concern over pesticide residues in fruits and vegetables necessitates the development of efficient monitoring systems to ensure food safety. This research presents a comprehensive solution for real-time pesticide monitoring using a hardware setup based on Arduino and IoT integration. The proposed system incorporates a pH sensor, gas sensor, ESP camera, LCD module, and ESP32 camera for continuous monitoring of fruits and vegetables. The hardware setup collects data on pH levels and gas emissions, providing crucial information about the quality and safety of the produce. The ESP32 camera captures images of the fruits or vegetables, and the data is transmitted to a mobile device in real-time for user-friendly monitoring. Additionally, the system enables remote access to the ESP32 camera output, enhancing accessibility and convenience for users. To enhance the analysis of pesticide contamination, a multi-stage process is proposed for the ESP32 camera output. Initially, the captured images are transmitted to a PC for pre-processing, segmentation, and feature extraction. Subsequently, a machine learning model is employed to analyze the extracted features and identify the presence of pesticides. The output of the ML model provides valuable information by displaying the name of the specific fruit or vegetable and indicating the level of pesticide contamination. This integrated approach offers a practical and efficient solution for real-time monitoring of pesticide residues in fruits and vegetables. The combination of Arduino-based hardware, IoT connectivity, and machine learning analysis ensures a comprehensive and user-friendly system for assessing the safety of agricultural produce. The proposed methodology holds the potential to contribute significantly to food safety practices and facilitate informed decision-making in the agricultural and consumer sectors.

I. INTRODUCTION

Pesticides are chemical agents extensively used in agriculture to control pests and improve crop yield and quality. These substances are applied at various stages of crop cultivation and during post-harvest storage. While their use has significantly enhanced agricultural productivity, improper or excessive application can lead to hazardous pesticide residues in the produce reaching consumers. Practices such as the inappropriate selection of pesticide types, over-application, and premature harvesting before the safe degradation of chemicals contribute to unsafe residue levels in food products. To address these concerns, regulatory agencies worldwide have established Maximum Residue Limits (MRLs) for pesticides in fruits and vegetables. Consequently, there has been a growing emphasis on monitoring pesticide residues in food to ensure consumer safety and environmental sustainability. Traditionally, analytical techniques such as Gas Chromatography (GC), Liquid Chromatography (LC), and their advanced variants (GC-MS and LC-MS/MS) are employed for pesticide detection. Although these techniques offer high accuracy and sensitivity, they are time-consuming, costly, require skilled personnel, and are impractical for widespread, on-site deployment. Moreover, they lack remote monitoring capabilities and real-time responsiveness.

In recent years, biosensor technologies have emerged as a viable alternative for rapid, on-field pesticide detection. These devices are cost-effective, compact, and well-suited for environmental and food safety applications. With the rise of smart technologies, the integration of the Internet of Things (IoT) with sensor-based systems has revolutionized data acquisition and real-time monitoring. IoT allows interconnected devices—sensors, microcontrollers, and communication modules—to collaboratively gather, process, and transmit data to remote platforms for analysis and decision-making.

This research aims to develop an IoT and machine learning (ML)-enabled system for real-time pesticide residue detection in fruits and vegetables. By combining hardware components such as pH and gas sensors with cloud connectivity and image-based ML classification, the system provides a non-invasive, low-cost, and efficient solution for ensuring food safety in commercial and domestic environments.

II. LITERATURE SURVEY

Several research works have focused on developing systems for pesticide residue detection using various technologies. Aradhana B S et al. [1] proposed a multi-sensor system that uses fruit recognition via image processing along with sensors such as IR, ethylene gas, and LDR to detect ripeness and pesticide contamination in fruits and vegetables. This method compares sensor outputs against threshold values and displays results on an LCD. Taotao Mu and Shengnan Wang [2] introduced a nano-SERS chip integrated with a smartphone-based Raman sensor. Their method enables rapid detection of 12 different pesticide molecules using trace samples, offering a portable and sensitive detection approach. Similarly, Hyeokjung Kim and Yeji Kim [3] developed a colorimetric paper sensor that changes color in the presence of pesticides through competitive inhibition reactions, making it suitable for quick and easy screening.

M. Villar Navarro and Miguel A Cabezon [4] applied second-order fluorescence data with unfolded partial least squares to identify pesticides like carbaryl and thiabendazole in fruits. Their method was precise and useful for overlapping spectral data. Fabio Leccese et al. [5] presented an “electronic nose” system using gas sensors to detect pesticides, where sensor data were analyzed using LabVIEW and transmitted online, offering a smart environmental monitoring tool. A simpler system using pH and electrical conductivity sensors was proposed by Deepali Gupta and Balwinder Singh [6], where the juice of vegetable samples was analyzed to compare conductivity and pH before and after pesticide exposure. Tejkanwar Singh and Mandeep Singh [7] designed a handheld device using NDVI calculations through IR sensors and photodiodes to distinguish between organic and inorganic samples, displaying results graphically.

Dong Kyu Lee and Giyoung Kim [8] developed a highly sensitive THz-based spectroscopy system that detects pesticides using nano-antenna arrays. This method provided accurate spectral reflections of pesticide presence. Similarly, Huang Xingjiu and Liu Jinhuai [9] used SnO2 sensors in a temperature modulation setup to analyze gas-phase pesticides, offering a method for identifying pesticide concentrations using resistance values. Yiqun Zhu and Liangbao Yang [10] used a D-SERS method where silver nanoparticle-coated filter paper was swabbed on produce surfaces to collect samples. This low-cost and effective method allowed field-level pesticide detection. Dr. Bhandri Ranu [11] employed the QuEChERS method for detecting pesticides in vegetable and fruit samples, using centrifugation and chromatographic analysis for residue quantification.

III. EXISTING METHODOLOGY

In existing pesticide detection systems, traditional and modern methods have been explored to identify chemical residues in fruits and vegetables. Conventional laboratory techniques such as Gas Chromatography (GC), Liquid Chromatography (LC), and Mass Spectrometry (GC-MS, LC-MS/MS) are commonly used due to their high accuracy and sensitivity. However, these methods are expensive, time-consuming, and require skilled professionals and well-equipped labs, making them unsuitable for on-field or real-time applications [2], [13].

Some recent approaches have used advanced hardware and sensor-based technologies. For instance, colorimetric paper-based sensors that undergo color changes in the presence of pesticide residues provide quick results using chemical reactions [3]. Similarly, methods involving SERS chips with smartphone-based Raman sensors have shown high sensitivity for detecting multiple pesticide compounds but are still limited by complexity and cost [2]. Other works have focused on electronic nose systems and gas sensors to identify the presence of toxic gases released by pesticide residues. These systems use commercial gas sensors integrated with microcontrollers and analyze the data using custom software or cloud platforms [5], [6].

Furthermore, systems like the NDVI-based handheld device [7] and pH/conductivity-based analyzers [6] attempt to make the detection process more portable and cost-effective. However, most of these systems still lack real-time monitoring capabilities, integration with IoT platforms, or efficient classification using AI or machine learning techniques. Most importantly, many of these methods do not combine sensor data with image processing or machine learning for accurate and automated classification. They also lack cloud-based connectivity for data storage and remote accessibility, which limits their scalability and ease of use in smart agriculture environments.

IV PROPOSED METHODOLOGY

The proposed system integrates Internet of Things (IoT) and Machine Learning (ML) technologies for the detection of pesticide residues in fruits and vegetables. It combines multiple sensors—including pH, gas (MQ135), temperature, and humidity sensors—with a NodeMCU ESP8266 microcontroller and an ESP32 camera. The sensors collect chemical and environmental data from the produce, while the camera captures images for analysis. Image processing techniques such as pre-processing, segmentation using K-means clustering, and feature extraction are applied to isolate and evaluate relevant image data. The sensor values and image features are then input into a pre-trained machine learning model to classify the type of fruit and determine whether pesticide residues are present. All data is sent to the cloud platform Ubidots via Wi-Fi, enabling real-time monitoring and visualization. This approach offers a low-cost, non-destructive, and portable solution that improves food safety through rapid, automated pesticide detection.

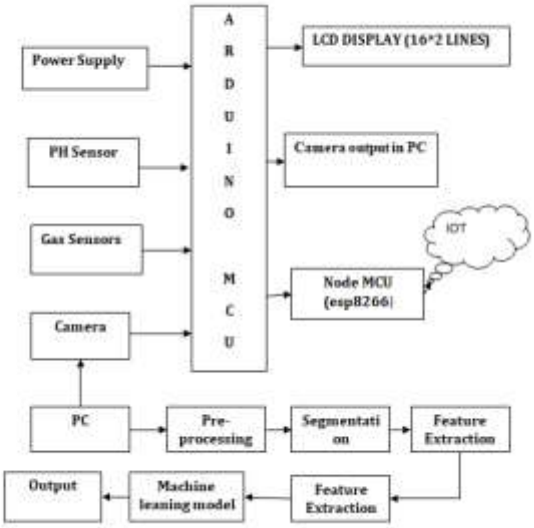
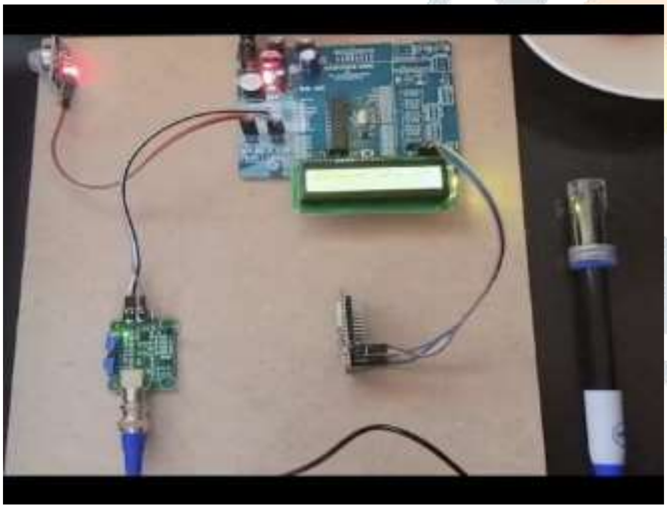
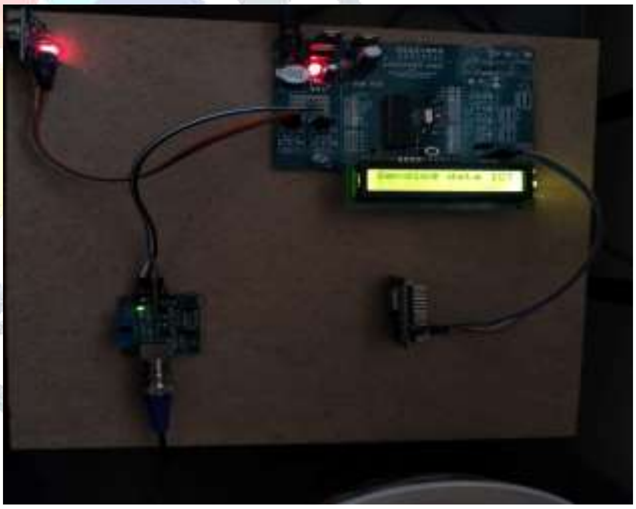
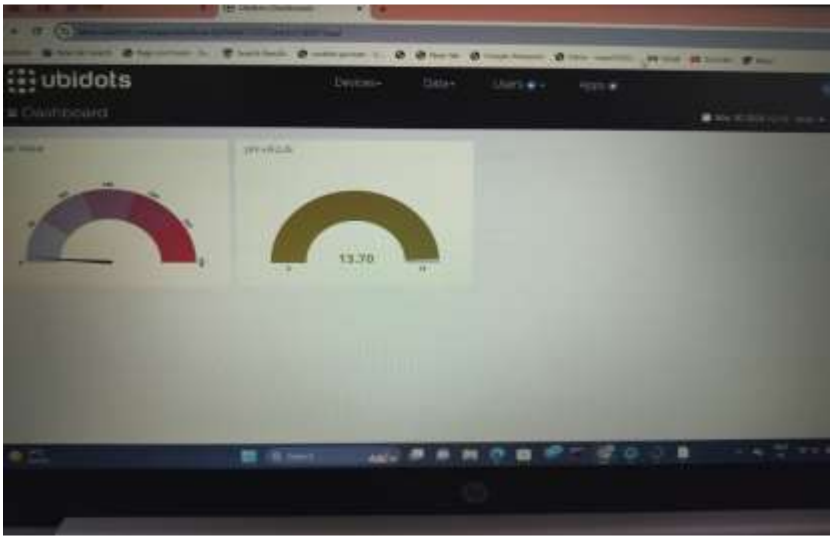


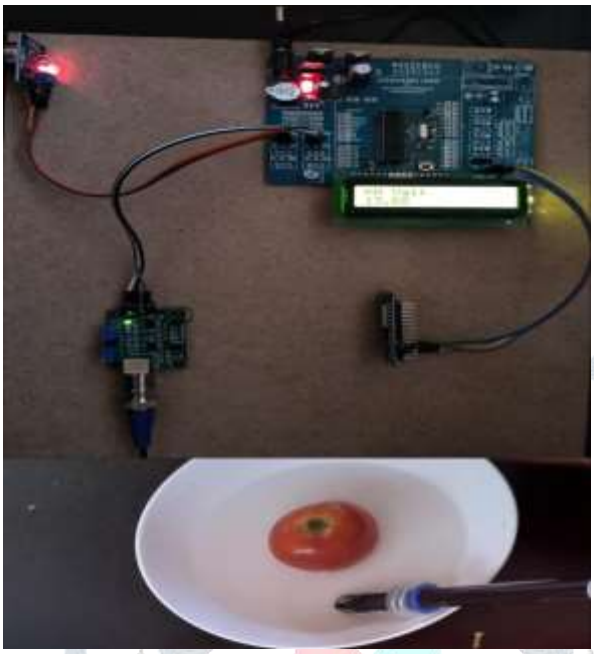
Figure 1: Proposed Architecture

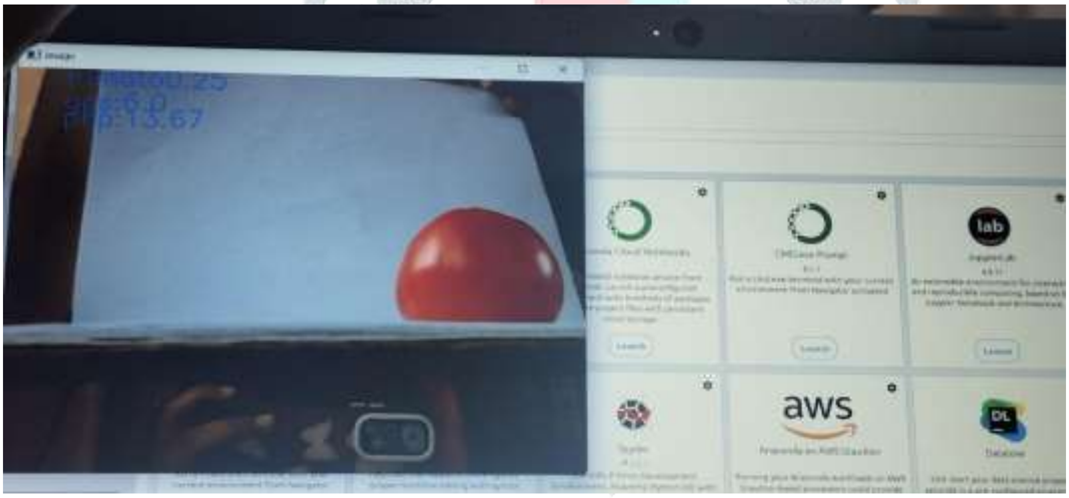
V. RESULTS & DISCUSSIONS











VII. CONCLUSION

In conclusion, the proposed IoT and Machine Learning-based system offers an innovative, real-time, and cost-effective solution for detecting pesticide residues in fruits and vegetables. By integrating multiple sensors with a microcontroller and a camera module, the system effectively monitors environmental and chemical parameters while also analyzing visual features through image processing and machine learning algorithms. The use of cloud platforms like Ubidots allows for remote data monitoring and accessibility, making the system highly practical for use in markets, farms, and households. This non-destructive method enhances food safety, reduces reliance on expensive laboratory equipment, and empowers consumers and producers with timely information about produce quality. With further improvements in dataset size and algorithm training, the system holds strong potential for large-scale deployment in smart agriculture and food safety management.

VIII. FUTURE SCOPE

The proposed system lays the groundwork for future advancements in smart agriculture and food safety monitoring. In the future, the system can be enhanced by integrating advanced deep learning algorithms for more accurate image classification and pesticide detection across a wider variety of fruits and vegetables. Expanding the dataset with diverse and region-specific samples will improve the model’s robustness and generalization. Additionally, the hardware can be upgraded with more sensitive and selective sensors to detect a broader range of chemical compounds. The integration of GPS modules and mobile application interfaces can enable location-based tracking of contaminated produce, contributing to effective supply chain monitoring and traceability. Furthermore, with the incorporation of solar-powered modules and energy-efficient hardware, the system can be made suitable for use in remote and rural agricultural settings. These enhancements will make the system more scalable, reliable, and impactful in ensuring food safety and public health on a larger scale.

IX. REFERENCES

[1]. Aradhana B S ,Aishwarya Raj, Praveena K G, Joshy M, Reshmi B S. “Quality And Pesticides Detection In Fruits and Vegetables”. 2021 Journal of Emerging Technologies and Innovative Research (JETIR), May 2021, Volume 8, Issue 5.

[2]. TaotaoMu ,Shengnan Wang ,Tianshu Li, Bing Wang. “Detection of Pesticides Residues Using Nano-SERS Chip and a Smartphone – Based Raman Sensor”. IEEE Journal of Selected Topics in Quantum Electronics, vol. 25, no.2, pp. 1-6, March-April 2019.

[3]. Hyeokjung Kim, Yeji Kim, Su Jung Park, Chanho Kwon. ‘’Development of Colorimetric Paper Sensor for Pesticide Detection Using Competitive-inhibiting Reaction’’. Published online: 22 October, 2018 The Korean BioChip Society and Springer 2018

[4]. M.Villar Navarro, Miguel A Cabezon, Patricia Cecilia Damiani. ‘’Simultaneous Determination of Pesticides in Fruits by Using Second-Order Fluorescence Data Resolved by Unfolded Partial Least-Squares Coupled to Residual Bilinearition’’. October 2018, Journal of Chemistry .2018: 1-17

[5]. Fabio Leccses, CagnettiSabino, Simonettatuti, Igor Luisetto. Electronic nose for pesticides detection: A first realization. 2017 IEEE International Worshop on Metrology for AeroSpace .

[6]. Deepali Gupta, Balwinder Singh Lakha, Harpreet Singh. ‘’Design and Development of Pesticide Residue Detection System using EC and pH Sensor’’. March 2016 International Journal of Engineering and Manufacturing 6(2):10-17.

[7]. Tejkanwar Singh, Mandeep Singh. ‘’Hand Held Device for Detection of Pesticides using NDVI’’. November 2016. International Journal of Computer Applications 154(9): 29-35.

[8]. Dong Kyu Lee, Giyoung Kim, Chulki Kim, Young Min Jhon. ‘’ Ultrasensitive Detection of Residual Pesticides Using THz Near-Field Enhancement’’. IEEE Transactions on Terahertz Science and Technology, vol 6, no. 3, pp. 389-395, may 2016.

[9]. HaungXingjiu, Liu Jinhuai, Pi Zongxin, Yu Zengliang. ‘’ Ultrasensitive Detection of Residual Pesticides Using THz Near-Field Enhancement’’. IEEE Transactions on Terahertz Science and Technology, vol 6, no. 3, pp. 389-395, may 2016.

[10]. Yiqun Zhu, Minqiang Li, Daoyang Yu, Liangbao Yang. ‘’ A novel paper rag as ‘D- SERS’ substrate for detection of pesticide residues at various peels’’.School of Chemistry and Chemical Engineering, Anhui University, Hefei 230039, China.

[11] Dr. BhandriRanu “Pesticide Residue in Vegetables and Fruits”. Asst Professor Chemistry, malwa Institute of Technology, Indore, Madhya Pradesh, pp dec-2015

[12] GuoZhaol, YeminGuol, Xiangyou Wang. “A system for pesticide residue detection and agricultural products traceability based on acetylcholinesterase biosensor and internet of things”.School of Agriculture and Food Engineering, Shandong University of Technology, NO.12, Zhangzhou.Published on February 2011.

[13] RohanDasika, SidharthTangirala and PadmajaNaishadham “Pesticide residue analysis of fruits and vegetables”. Department of chemistry, Osmania University, Hyderabad, India. Accepted on December 2011.