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Detection of Pesticides in Fruits and Vegetables Using IoT and ML

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ABSTRACT :

The widespread use of pesticides in agriculture has led to significant concerns about food safety and public health. Conventional methods for pesticide residue detection are often time-consuming, expensive, and require complex laboratory infrastructure. To address these limitations, this project proposes an integrated system leveraging Internet of Things (IoT) and Machine Learning (ML) technologies for real-time detection of pesticide residues in fruits and vegetables.

The proposed system employs smart sensors capable of detecting chemical signatures associated with common pesticides. These sensors are embedded into a portable IoT device that collects and transmits data wirelessly to a cloud-based platform. The collected data is then processed using machine learning algorithms trained on labeled datasets to accurately identify the presence and concentration of pesticide residues.

The ML model utilizes techniques such as Support Vector Machines (SVM), Random Forest, and Neural Networks to achieve high accuracy in classification and prediction tasks. The system provides real-time feedback via a user-friendly mobile or web application, enabling consumers, vendors, and regulatory bodies to make informed decisions about food safety.

This approach not only enhances the efficiency and accessibility of pesticide detection but also contributes to the development of a smarter and safer food supply chain. The integration of IoT and ML presents a scalable, cost-effective, and non-invasive solution for addressing one of the most pressing challenges in modern agriculture and food security.

Introduction

Pesticides are extensively used in modern agriculture to protect crops from pests and increase yield. While they play a crucial role in ensuring food security, the excessive and improper use of these chemicals can leave harmful residues on fruits and vegetables. Consumption of such contaminated produce poses serious health risks, including neurological disorders, hormonal imbalances, and even cancer. As a result, detecting pesticide residues in food has become a matter of global concern.

Traditional methods of pesticide detection, such as gas chromatography and mass spectrometry, though accurate, are often expensive, time-consuming, and require well-equipped laboratories with skilled personnel. This makes them impractical for widespread, real-time monitoring—especially in developing regions or at the consumer level.

To overcome these limitations, this study explores a novel solution that combines Internet of Things (IoT) and Machine Learning (ML) technologies to enable real-time, cost-effective, and portable pesticide detection. IoT devices equipped with chemical or biosensors can collect data from fruit and vegetable surfaces, which is then analyzed using trained ML models to detect the presence and concentration of specific pesticide compounds.

The integration of IoT and ML not only enhances the speed and accuracy of detection but also allows for remote monitoring, data logging, and automated decision-making. Such a system has the potential to revolutionize how we ensure food safety— empowering farmers, vendors, and consumers to take timely action and reduce health risks associated with pesticide exposure.

Problem Statement :

The increasing use of pesticides in agriculture has led to a significant rise in the presence of harmful chemical residues on fruits and vegetables.

These pesticide residues, if not properly monitored, can pose serious health risks to consumers, including long-term diseases such as cancer, reproductive disorders, and neurological issues. Despite the critical nature of this issue, current detection methods are predominantly lab-based, expensive, time-consuming, and inaccessible to the general public and small-scale farmers. There is a clear need for a fast, accurate, and user-friendly solution that enables real-time detection of pesticide residues in produce without relying on complex laboratory infrastructure. The absence of such a system limits the ability of consumers, vendors, and regulatory authorities to ensure food safety and compliance with health standards.

Objective :

The main objective of this project is to develop a smart, real-time system that can detect pesticide residues in fruits and vegetables using Internet of Things (IoT) and Machine Learning (ML) technologies. This system aims to utilize IoT-based sensors to collect relevant data on chemical properties from the surface of produce. The data will be analyzed using machine learning algorithms trained to identify and classify pesticide contamination with high accuracy.

Literature Review

1. **IoT with gas sensors (E-nose) Authors: Patel et**

Focus Area:

Focused on developing a real-time detection system for pesticide residues using an Electronic Nose (E- nose) integrated with IoT technology. The core idea was to use gas sensors that can detect volatile organic compounds (VOCs) emitted from pesticide- contaminated fruits and vegetables.A Review Paper on Pre and Post Accident Detection and Alert System: an IoT Application for Complete Safety of the Vehicles

These VOCs serve as indicators of chemical contamination. The E-nose mimics the human olfactory system by using an array of gas sensors (such as metal oxide sensors) to detect and differentiate these chemical signatures.

2. **SVM and Random Forest ML models Authors:** Sharma et

Focus Area:

Sharma et al. (2021) focused on building a machine learning-based classification system to detect the presence of pesticide residues in fruits and vegetables. Their study involved collecting data from various sensors (e.g., chemical, optical, or spectroscopic sensors), and applying Supervised Machine Learning models—specifically Support Vector Machines (SVM) and Random Forest (RF)— to classify produce as either contaminated or safe.

3. **NIR Spectroscopy with IoT connectivity**

Authors: Kumar & Singh

Focus Area:

Kumar & Singh (2020) explored the integration of Near-Infrared (NIR) Spectroscopy with IoT technology to detect pesticide residues non-destructively in fruits and vegetables. Their study centered on developing a portable, smart sensing system capable of collecting spectral data from produce, transmitting it wirelessly, and analyzing it using cloud-based or edge-based machine learning models.

4. **Deep Learning (CNN) on hyperspectral images Authors:** Chen et

Focus Area:

Chen et al. (2023) focused on using Convolutional Neural Networks (CNNs) to analyze hyperspectral images of fruits and vegetables for the detection and classification of pesticide residues. Their study combined advanced image-based chemical analysis with deep learning techniques to offer highly accurate, non-invasive pesticide detection.

5. **IoT sensors + cloud ML platform Authors :** Rani & Verma

Focus Area:

Rani & Verma (2022) focused on building an end- to-end IoT system that uses sensor data collected from fruits and vegetables and processes it through a cloud-based machine learning platform. The system was designed to enable real-time, remote monitoring and analysis of pesticide residues, with smart notifications and decision support.

6. **Regression analysis Authors:** Ghosh et **Focus Area:**

Ghosh et al. (2020) focused on quantitatively estimating pesticide residue concentrations in fruits and vegetables using regression analysis applied to sensor data. Unlike classification models that label produce as simply “safe” or “contaminated,” this study aimed to predict the exact residue level (e.g., in ppm or mg/kg), helping determine if it exceeds the Maximum Residue Limit (MRL) set by regulatory bodies.

7. **Smartphone IoT device with colorimetric sensors**

Authors: Ali et

Focus Area:

Ali et al. (2022) developed a smart, portable, and low-cost pesticide detection system using colorimetric sensors integrated with a smartphone- based IoT device. The primary focus was on enabling rapid, on-site testing of fruits and vegetables for pesticide residues, using visible color changes as an indicator of contamination, captured and analyzed through a mobile app.

8. Wireless Sensor Network + ML analytics Authors: Zhou et

Focus Area:

Zhou et al. (2021) concentrated on developing a Wireless Sensor Network (WSN) framework integrated with Machine Learning (ML) analytics to monitor and detect pesticide contamination in agricultural fields. The key focus was on distributed sensing, automated data analysis, and real-time decision-making to ensure safe produce before harvest or distribution.

System Architecture

The integration of Internet of Things (IoT) and Machine Learning (ML) technologies presents a transformative approach for addressing critical challenges in food safety, particularly the detection of pesticide residues in fruits and vegetables. Conventional analytical techniques such as gas chromatography and mass spectrometry, while accurate, are typically expensive, time-intensive, and laboratory-bound, making them unsuitable for real-time or large-scale field deployment. The adoption of IoT and ML enables the development of intelligent, non-destructive, and scalable systems capable of monitoring produce quality in real-time.

IoT systems consist of a network of interconnected devices and sensors that collect, transmit, and process data autonomously. In the context of pesticide detection, IoT devices are equipped with chemical, optical, or colorimetric sensors that can identify the presence of pesticide residues based on various physical or chemical properties. These sensors are embedded in microcontroller-based platforms (e.g. ESP32) that handle data acquisition and communication using wireless protocols such as Wi-Fi

Machine Learning enables intelligent data interpretation by learning patterns and relationships from large datasets. In pesticide detection, ML algorithms are trained on sensor data to:

ESP32 (Microcontroller) :

The ESP32 microcontroller is a low-cost, Wi-Fi and Bluetooth-enabled chip used to collect data from sensors and transmit it wirelessly. In pesticide detection systems, it connects with sensors to process and send real-time data to the cloud for machine learning analysis.

Roles:

- Collects real-time data from connected sensors (e.g., gas, colorimetric, optical).
- Processes and filters sensor data at the edge (basic preprocessing).

Supports low-power operation for field-based, portable systems.

Sensors :

a) Chemical Gas Sensor :

- **Type :** Chemical gas sensor (metal oxide semiconductor)
- **Role :** Detects airborne gases such as ammonia, benzene, alcohol, smoke, and certain pesticide vapors (e.g., organophosphates).
- **Output :** Analog voltage signal (0–5V), which varies based on gas concentration. Can also be connected via ADC to microcontrollers like ESP32 for digital processing.

b) Chemical Gas Sensor :

- **Type :** Sensor for alcohol gas.
- **Function** Detects flammable gases and vapors such as LPG, methane, hydrogen, smoke, and alcohol — useful for sensing certain volatile compounds released from pesticide residues during decomposition.
- **Output** : Analog voltage signal (0–5V), which varies with gas concentration. Also provides a digital output through an onboard comparator when a set threshold is reached.
- **Type :** DC regulated power source

  Role : Powers components like the ESP32, sensors, and LCD display, ensuring stable and reliable system operation.
- **Output** : Constant 5V DC, suitable for most microcontrollers and modules in IoT systems.

Connectivity :

a) WiFi Module:

- **Type :** Wireless communication module (e.g., ESP32 module)
- **Role :** Enables wireless transmission of sensor data to cloud servers, mobile apps, or web dashboards for real-time monitoring and analysis.
- **Output :** Digital data packets (e.g., via HTTP, MQTT protocols) transmitted over Wi-Fi network to remote platforms.

b) Blynk Cloud:

- **Type :** IoT cloud platform for device management and data visualization
- **Role :** Receives data from the ESP32 via Wi-Fi, stores it, and displays real-time sensor values (e.g., gas levels, temperature) on the Blynk mobile app/dashboard.
- **Output :** Visual and interactive output such as graphs, gauges, and alerts on a smartphone or web interface.

Flow Chart:

c) Temperature and Humidity Sensor :

- **Type :** Digital sensor (capacitive humidity + thermistor-based temperature)
- **Role :** Monitors environmental conditions that influence pesticide residue degradation and sensor accuracy.
- Helps in calibrating other sensors and ensuring reliable detection results.
- **Output :** Digital signal (e.g., in °C for temperature and %RH for humidity), typically transmitted over a single-wire protocol or I2C/SPI.

3.1 Display :

- **Type** : Alphanumeric LCD (16 columns × 2 rows)
- **Role :** Displays sensor readings, such as gas levels, temperature, humidity, and pesticide status messages in real-time.
- **Output :** Text-based output (e.g., "Temp: 27°C", "Pesticide: Unsafe") using characters and numbers.

3.2 Power Supply :

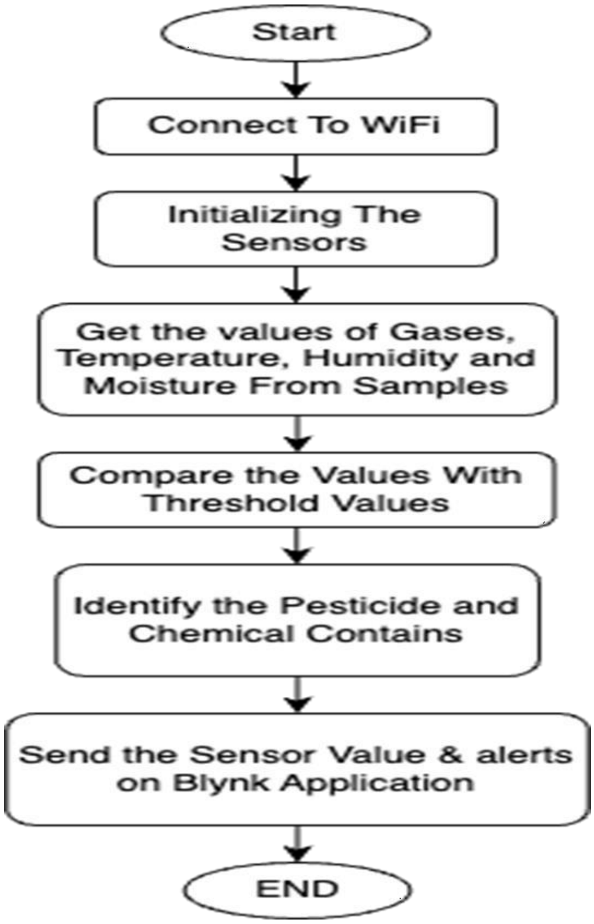

Fig : Flow Diagram for Detection of Pesticides in Fruits and Vegetables Using IoT and ML

Advantages

1. **Real-Time Monitoring:** Enables instant detection and alerting of harmful pesticide levels without delays.
2. **Non-Destructive Testing:** Analyzes produce without damaging it, making it ideal for supply chains and retail.
3. **Remote Accessibility:** Data can be monitored from anywhere via cloud platforms or mobile apps.
4. **High Accuracy with ML:** Machine learning models improve detection precision by learning complex patterns from sensor data.
5. **Automation and Scalability:** Systems can run autonomously and scale across farms, markets, and warehouses.

Conclusion

This project successfully developed an IoT-based system for detecting pesticide residues in fruits and vegetables. By integrating a diverse range of sensors, including gas sensors, temperature and humidity sensors, and moisture sensors, the system can effectively monitor the quality and safety of produce.

The implementation of machine learning algorithms further enhances the system's accuracy and reliability. By analyzing historical data and identifying patterns, the system can make informed decisions about the presence of pesticides.

The integration of the Blynk IoT platform enables remote monitoring and control, allowing users to access real-time data and take necessary actions. The 16x2 LCD display provides a local interface for monitoring sensor readings and alerts.

While this project demonstrates the potential of IoT technology in food safety, further research and development are needed to improve the system's accuracy, sensitivity, and robustness. Future work may involve exploring advanced sensor technologies, refining machine learning algorithms, and integrating additional features like automatic data logging and remote calibration.

REFERENCES :

1. R. Kanmani, R. Maheswar, A. Sureshkumar, A. Mugilan and V. Praveena, "Non-destructive Approach to Detect Pesticides in Fruits and Vegetables using IoT Technology," 2020
2. International Conference on Computer Communication and Informatics (ICCCI), Coimbatore, India, 2020.
3. Detection and Alert System: an IoT Application for Complete Safety of the Vehicles," Maulana Azad National Institute of Technology, Bhopal, India, 2022.
4. T. T. Leonid, Hemamalini, N. T and Krithika, "Fruit quality detection and classification using Computer Vision Techniques," 2023 Eighth International Conference on Science Technology Engineering and Mathematics (ICONSTEM), Chennai, India, 2023.
5. Gharat, Anisha & Bamble, Swati. (2020). Senmi System - a Pesticides Detection system from fruits, vegetables and agricultural products.
6. Tanmay Thorat, B.K. Patle, Manas Wakchaure, Leena Parihar, Advancements in techniques used for identification of pesticide residue on crops, Journal of Natural Pesticide Research, Volume 4, 2023.
7. S.Saran, P. Pravallika, K. Gopichand, U. Sudheer, G.V. Vinod, 2024, Detection of Pesticides in Organic Fruits and Vegetables Using IOT and ML, INTERNATIONAL JOURNAL OF ENGINEERING RESEARCH & TECHNOLOGY (IJERT).
8. SUN, Xia & WANG, Xiangyou. (2013). A Design of Portable Pesticide Residue Detection System Based on the Enzyme Electrode. Sensors and Transducers.
9. Raja Nehru, Chiu-Wen Chen, Cheng-Di Dong, A review of smart electrochemical devices for pesticide detection in agricultural food and runoff contaminants, Science of The Total Environment, Volume 935, 2024.
10. Sujitha, S. et al. "Artificial Intelligence and IoT based detection of pesticide in organic fruits and vegetables." 2023 International Conference on Intelligent and Innovative Technologies in Computing, Electrical and Electronics (IITCEE) (2023).