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CITRUS FRUIT QUALITY ASSESSMENT: GAS SENSOR APPROACH FOR PESTICIDE RESIDUE AND RIPENESS EVALUATION

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ABSTRACT
The primary goal for quality evaluation of citrus fruits is to ensure that the product meets or exceeds established standards for safety, freshness, taste, and nutritional content. Quality evaluation aims to guarantee a consistent and high- quality product for consumers, meeting regulatory r equirements and maintaining the reputation of the brand or product. Citrus fruits, which are cultivated worldwide, have been recognized as some of the most high-consumption fruits in terms of energy, nutrients and health supplements. The use of pesticides is widespread in citrus fruits production for pre- and post-harvest protection and many chemical substances may be applied in order to control undesirable moulds or insects. Traditional methods for pesticide detection rely on time-consuming laboratory techniques, while ripeness assessment often involves subjective visual inspections. The proposed solution addresses these limitations by integrating specialized gas sensors into a portable device, allowing for on-site and real-time analysis. The pesticide detection module exhibits high sensitivity to common pesticides, providing rapid identification of harmful residues on citrus fruits. Simultaneously, the ripeness assessment module employs ethylene gas sensors, accurately measuring fruit maturity through the detection of this natural plant hormone. The integration of these modules streamlines fruit quality control processes, offering a comprehensive solution for farmers, distributors, and consumers. By mitigating the reliance on labor-intensive and subjective methods, this gas sensor system enhances the efficiency and reliability of citrus fruit quality assessments. This innovation contributes to the advancement of sustainable agricultural practices, ensuring the safety and premium quality of citrus fruits throughout the production and supply chain.

Keywords-
citrus fruit, pesticide residue, quality evaluation, ripeness.

INTRODUCTION
The origin of citrus fruits is generally attributed to Southeast Asia1, a biodiversity hotspot13 whose climate is influenced by both East and South Asian monsoons. Principal coordinate analysis of 58 citrus accessions based on nuclear genome pairwise distances and metric multidimensional scaling. The first two axes separate the three main citrus groups (lemons, pummels and tangerines) with interspecific hybrids (oranges, grapefruits, lemons and limes). (Gutherie, 1995)
The classification of citrus is complexed however, the genus Citrus consists of more than 100 species. The number of species is variable and this species variation in a single genus is due to the admixture of wide morphological diversity, intra- and interspecific sexual compatibility, apomixis, and spontaneous mutations. However, intergenic hybrids such as citranges, citrumelos, and citrandarins, citremons, citradias, and citrumquats are also reported and are getting increasing importance. Several indigenous varieties are developed and consumed locally in specific regions. The citrus fruits are tangy with pleasant flavor and taste, a combination of sweet and sour flavors. Oranges and mandarins are predominant species of genus Citrus, marketed as fresh or processed juice.

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Figure 1 Citrus fruit

Classification of citrus fruits is complicated, but there are more than 100 species in the citrus family. The number of species varies, and this variety of species within a genus is due to mixing of wide morphological diversity, intraspecific and interspecific sexual compatibility, apomixis, and spontaneous mutations. However, intergenic hybrids such as citranges, citrumelos and citrandarines, citronomas, citradias and citrumquats have also been reported and are growing in importance. In certain regions, several local varieties are developed and consumed locally. Citrus fruits are sharp and have a pleasant taste and flavor, a combination of sweet and sour taste. Oranges and tangerines are the dominant species of the genus Citrus, which are marketed as fresh or processed juice.

Fruit citrus is facing increasing biotic and abiotic factors due to the changing climate worldwide. Among the abiotic factors, temperature variation and sudden cold are the main limiting factors, while bacteria, viruses, viroids, nematodes, fungi and plant plasmas are important biotic factors. Some factors cause a huge drop in production and quality, while others can completely destroy the citrus industry. Due to the genetic and reproductive characteristics of the plant, citrus reproduction by conventional methods is not recommended. Interdisciplinary interventions based on omics and biotechnology can combat such external factors and improve fruit health and nutritional value. (A.C. Matheyambath, 2016)

Citrus fruits, comprising essential commodities in the global agricultural market, face ongoing challenges related to pesticide residues and the accurate determination of ripeness. Current methods for pesticide detection predominantly involve cumbersome laboratory techniques, which are time-consuming and resource-intensive. Similarly, the assessment of ripeness relies on subjective visual inspections or manual sampling, leading to inconsistencies in fruit quality control. In response to these challenges, this research proposes an integrated gas sensor system that aims to revolutionize the monitoring process for citrus fruits. By simultaneously addressing pesticide detection and ripeness assessment through a portable and efficient platform, this innovative approach seeks to enhance the speed, accuracy, and accessibility of quality control measures in the citrus industry. The integration of advanced gas sensors into a single device provides a real-time, on-site solution, offering benefits to farmers, distributors, and consumers by ensuring both the safety and quality of citrus fruits throughout the production and supply chain.

Furthermore, the versatility of this gas sensor system lends itself to a wide range of applications beyond citrus fruits. From other agricultural produce to industrial settings where gas detection is crucial, the potential for innovation and impact knows no bounds. As such, this project represents not only a solution to existing challenges but also a catalyst for future advancements in sensor technology and agricultural practices.

In essence, the introduction of this gas sensor system marks the dawn of a new era in citrus farming—one characterized by efficiency, reliability, and sustainability. As we embark on this journey of innovation, let us seize the opportunity to redefine the future of agriculture and pave the way for a brighter, more resilient tomorrow.At the heart of this revolutionary gas sensor system lies a dedication to addressing longstanding challenges in citrus fruit quality assessment with unparalleled ingenuity and precision. Traditional methods, reliant on labor-intensive laboratory analyses and subjective visual inspections, have long been a bottleneck in the citrus supply chain, impeding efficiency and introducing uncertainties at every stage of production and distribution. However, through the innovative integration of specialized gas sensors into a portable device, this project pioneers a transformative approach that promises to redefine the standards of excellence in citrus farming.

PESTICIDE IN CITRUS FRUITS

As indicated by available reports, the potential for pesticide misuse in fruit production remains high (Mebdoua et al., 2017; United States Food and Drug Administration; [US FDA], 2017; European Food Safety Authority [EFSA], 2018) despite the maximum residue limits (MRL) enforced by the legislation of many countries. The MRL is the highest concentration of a pesticide that is legally tolerated in or on a food when the pesticide is applied correctly in accordance with good agricultural

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practice (Codex Alimentarius Commission, 2019). Compared to other food groups, fruits are recognized as a group containing higher levels of pesticide residues (Stachniuk, Szmagara, Czeczko, & Fornal, 2017). According to the US FDA Pesticide Residue Monitoring Program (2017), fruits have a higher percentage of detectable pesticide residues and a higher percentage of samples with residue levels exceeding the MRL than any other foods. In fact, the dietary intake of fruits is considered a major exposure pathway to pesticide residues in the general population (Chiu et al., 2018), especially when these foods are eaten uncooked and without peeling or trimming the outer layers (Bajwa & Sandhu, 2014; Stachniuk, Szmagara, Czeczko, & Fornal, 2017). imazalil was the most frequently detected pesticide in citrus fruits, followed by chlorpyrifos (studies from Croatia and Slovenia). In different fruits from South America, the three most frequently detected pesticides were thiabendazole (29%), imazalil (25%), and chlorpyrifos (17%) **.**

CITRUS FRUITS

LEMON:

Lemon, Citrus limon, could be a little evergreen tree within the family Rutaceae developed for its eatable natural product which, among other things, are used in a assortment of nourishments and drinks. The tree features a spreading, upright development propensity, few huge branches and solid thistles. The tree has huge, elongated or oval, light green clears out and produces purple-white blooms in clusters. The lemon natural product is an ellipsoid berry encompassed by a green skin, which ages to yellow, securing delicate yellow sectioned mash. Lemon trees can reach 3–6 m (10–20 ft) in tallness and can live for numerous a long time, coming to full natural product bearing capacity in roughly 40 years .

Figure 1.1 Lemon

ORANGE:

Orange, Citrus sinensis, is an evergreen tree in the family Rutaceae grown for its edible fruit. The orange tree is branched with a rounded crown and possesses elliptical or oval leaves which are alternately arranged on the branches. The leaves have narrowly winged petioles, a feature that distinguishes it from bitter orange, which has broadly winged petioles. The tree produces white flowers singly or clustered on a raceme. The fruit is a spherical berry with a green-yellow to orange skin covered in indented glands and a segmented pulpy flesh and several seeds. Orange trees can grow to a height of 6–15 m (16–49 ft) and can live for periods in excess of 100 years. Most plantations have an economic lifespan of around 30 years. Orange may also be referred to as sweet orange or navel orange and is believed to have originated from a wild ancestor in the border between Vietnam and China.

Figure 1.2 Orange

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MOSAMBI

C. limetta could be a little tree up to 8 m (26 ft) in tallness, with sporadic branches and moderately smooth, brownish-grey bark. It has various thistles, 15–75 mm (0.59–2.95 in) long. The petioles are barely but particularly winged, and are 8–29 mm (0.31–1.14 in) long. Clears out are compound, with acuminate pamphlets 50–170 mm (2.0–6.7 in) long and 28–89 mm (1.1–3.5 in) wide. Blossoms are white, 20–30 mm (0.79–1.18 in) wide. Natural products are oval and green, maturing to yellow, with greenish mash. The substance is white and approximately 5 mm (0.20 in) thick. In spite of the title sweet lime, the natural product is more comparable to a greenish orange in appearance.

Figure 1.3 Musambi

CITRUS DISEASE

Lemon scab may be a genuine illness of all lemon assortments developed in coastal ranges. The illness too influences Rangpur lime, and Harsh lemon rootstocks. Lemon scab is caused by the organism Sphaceloma fawcettii var. scabiosa. Side effects of Citrus scab assaults the natural product, clears out and twigs, creating marginally raised, unpredictable scabby or wart-like outgrowths. At to begin with these outgrowths are dim or pinkish, getting to be darker with age. They are more common on natural products than takes off. The raised knots related with scab can be befuddled with indications caused by the infection botrytis (which is unprecedented) or windrub scraped areas on youthful natural product. Spores of the organism are promptly delivered on the surface of scab injuries on youthful natural products all through the year. Spores of the organism are spread by wind and rain. The organism over-winters on the tree canopy, generally in scab injuries on natural product. Wet conditions support infection improvement. Most spores come from little tainted lemon natural products. Disease period of Lemon foliage is vulnerable to disease when the modern development flush is less than 25% extended. Youthful lemon natural products are helpless to contamination from quarter petal-fall to almost 12 weeks afterward (or 3-4 cm in breadth).

Figure 1.4 Scab Disease In Citrus Fruit

Citrus canker could be a assaulting bacterial infection debilitating citrus crops. Its major sorts are Asiatic Canker, Cancrosis B, and Cancrosis C, caused by Xanthomonas citri pv. citri (Xcc), Xanthomonas citri pv. aurantifolii pathotype-B (XauB), and pathotype-C (XauC), individually. The bacterium enters its have through stomata and wounds, from which it attacks the intercellular spaces within the apoplast. It produces erumpent corky necrotic injuries frequently encompassed by a chlorotic radiance on the clears out, youthful stems, and natural products, which causes dull spots, defoliation, decreased photosynthetic rate, crack of leaf epidermis, dieback, and untimely natural product drop in serious cases. Its primary pathogenicity determinant quality is pthA, whose variations are present in all citrus canker-causing pathogens. Nations where citrus canker isn't endemic receive diverse strategies to anticipate the presentation of the pathogen into the locale, annihilate the pathogen, and minimize its dispersal, while endemic locales require an coordinates administration program to control the malady.

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Figure 1.5 Canker Disease In Citrus Fruit

Citrus diseases caused by Alternaria spp. include Alternaria brown spot on tangerines (Citrus reticulata Blanco), leaf and fruit spot on rough lemons (Citrus jambhiri Lush.) and Rangpur limes (Citrus × limonia Osbeck), mancha foliar de los citricos affecting Mexican limes (Citrus aurantiifolia (Christm.) Swingle), and black rot on fruit of several Citrus spp. (41). According to unpublished research by T. L. Peever and L. W. Timmer, species of Alternaria are also often found as saprophytes on all aboveground tissues of citrus trees and may even colonize citrus leaves as endophytes. Citrus fruit with Alternaria black rot is a serious postharvest issue that can arise in the field before harvest. In the field, the disease most frequently affects navel oranges (C. sinensis (L.) Osbeck), tangerines, andand their hybrids in storage.

Figure 1.6 Rot Disease In Citrus Fruits

Among the citrus diseases caused by Alternaria spp. are Alternaria brown spot on tangerines (Citrus reticulata Blanco), mancha foliar de los citricos affecting Mexican limes (Citrus aurantiifolia (Christm.) Swingle), leaf and fruit spot on rough lemons (Citrus jambhiri Lush.) and Rangpur limes (Citrus × limonia Osbeck), and black rot on fruit of several Citrus spp. (41). Certain species of Alternaria are also often found as saprophytes on all aboveground tissues of citrus trees, and they may even colonize citrus leaves as endophytes, according to unpublished study by T. L. Peever and L. W. Timmer. A significant postharvest problem that can occur in the field prior to harvest is citrus fruit with Alternaria black rot. In the field, tangerines, navel oranges (C. sinensis (L.) Osbeck), and others are most commonly affected by the illness.

INTRODUCTION TO EMBEDDED SYSTEM

In Embedded systems represent the heart of modern technology, quietly orchestrating the seamless integration of hardware and software to perform specific functions. Ubiquitous, but often forgotten, systems form the backbone of many devices and applications that touch our daily lives. At the core of this technological symphony is embedded systems engineering, a discipline that combines hardware design, software and real-time computing to create compact, efficient and specialized computing solutions.

An embedded system is characterized by its integration. to a larger system, usually designed for a specific purpose or task. Unlike general-purpose computers, embedded systems are designed to perform predetermined functions, often with strict performance and reliability requirements. They find applications in various fields, from consumer electronics and automotive systems to medical devices and industrial automation.

Development of embedded systems involves finding a delicate balance between hardware and software. The hardware components are tailored to meet the specific requirements of the application, optimizing factors such as power consumption, size and processing speed. On the software side, embedded systems often use specialized operating systems or real-time operating systems (RTOS) to ensure precise timing and responsiveness.

Microcontrollers and microprocessors, the unsung heroes of embedded systems, act as the computing engines that drive

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these specialized devices.Their integration with sensors, actuators and communication interfaces is the basis of the functionality of embedded systems. As technology advances, the capabilities of embedded systems continue to expand, enabling the integration of artificial intelligence, machine learning and connectivity capabilities into an ever-growing range of devices.
In the age of the Internet of Things (IoT), where interconnected devices define the digital landscape , embedded systems play a key role. They are the silent devices that power smart homes, connected vehicles and industrial automation, leading to an unprecedented era of convenience and efficiency.

EMBEDDED SYSTEMS: A SYMPHONY OF PRECISION AND INNOVATION

As we navigate the complexity of today's technology landscape, the pervasive influence of embedded systems becomes increasingly evident. Carefully designed and integrated into various devices, these silent workhorses form the basis of countless industrial innovations. Embedded systems, characterized by their specificity and efficiency, represent the culmination of hardware and software organization necessary to perform special functions.
Program development in the field of embedded systems often involves the creation of firmware, the special software that resides on the device. memory microcontroller. This firmware is designed to perform certain operations efficiently and ensure the smooth operation of the device. The use of real-time operating systems (RTOS) or dedicated operating systems further emphasizes the need for precision and responsiveness, especially in applications where time is critical.
Microcontrollers are the unsung heroes of the embedded system with their small size and optimized functions. systems These tiny computing powers drive the functionality of devices ranging from the complex control systems of cars to the complexity of medical devices. The development of microcontrollers, characterized by increased processing power and advanced function integration, has taken the capabilities of embedded systems to new heights.
In an era dominated by the Internet of Things (IoT), embedded systems are at the forefront of networking. physical and digital worlds. They facilitate communication between devices, enabling smart homes, industrial automation and interconnected ecosystems. Combining embedded systems with new technologies such as artificial intelligence and machine learning will further expand their horizons, paving the way to autonomous systems and smart devices.

ARTIFICIAL INTELLIGENCE

Artificial intelligence (AI) is the simulation of human intellectual processes by machines, especially computer systems that can even imitate human behavior. Its applications are in computer vision, natural language processing, robotics, speech recognition, etc. The benefits of using artificial intelligence include better customer experience, faster time to market, improved product development enabling cost optimization, improved employee productivity and improved operational efficiency.
Machine learning (ML) is a subset of artificial intelligence programmed to think independently, interact socially, learn new information from information given, and adapt and evolve with experience. Although the training time of deep learning (DL) methods is more than that of machine learning methods, this is compensated by a higher accuracy in the former case. Also, since DL is automated, unlike ML, it does not require a large domain to achieve the desired results.

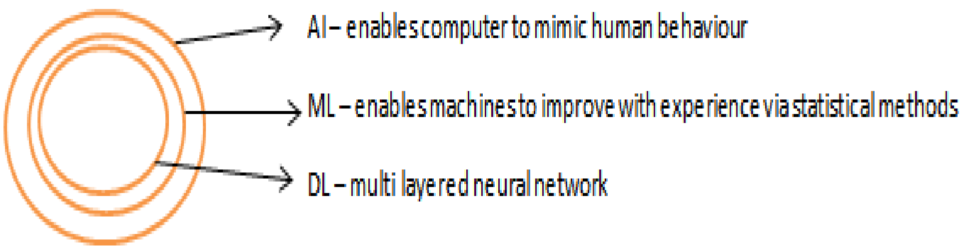

Figure.1.7. Artificial Intelligence

DEEP LEARNING

Deep learning is a subfield of machine learning that deals with algorithms called artificial neural networks inspired by the structure and function of the brain. Deep learning achieves great power and flexibility by learning to represent the world as a hierarchy of nested concepts, where each concept is defined in relation to simpler concepts and more abstract representations are computed from less abstract concepts. Convolutional Neural Network (CNN), which is a deep

learning algorithm used to diagnose human disease.
Deep Learning has some advantages such as,

- Works with large amount of data
- Highly depends on state-of-the-art machine
- Solves the problem end to end
- Needs longer time to train

Deep learning is a subfield of machine learning that deals with brain structure and function inspired algorithms called artificial neural networks. Deep learning achieves great power and flexibility by learning to represent the world as a hierarchy of nested concepts, where each concept is defined in relation to simpler concepts and more abstract representations are computed from less abstract concepts.

A CONVOLUTIONAL NEURAL NETWORK

In profound learning, a convolutional neural organize (CNN, or ConvNet) could be a lesson of profound neural systems, most commonly connected to dissecting visual symbolism. They have applications in picture and video acknowledgment, recommender frameworks, picture classification, Picture division, restorative picture investigation, normal dialect preparing, brain-computer interfacing, and monetary time arrangement. The title “convolutional neural network” shows that the organize utilizes a scientific operation called convolution. Convolutional systems are a specialized sort of neural systems that utilize convolution in put of common lattice increase in at slightest one of their layers.

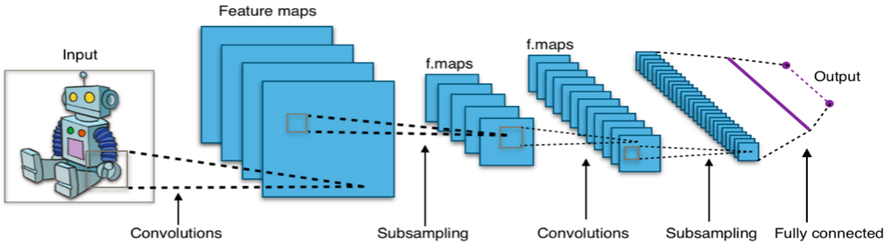

Figure 1.8 CNN Architecture

A convolutional neural arrange comprises of an input layer, covered up layers and an yield layer. In any feed-forward neural arrange, any center layers are called covered up since their inputs and yields are conceal by the enactment work and last convolution. In a convolutional neural arrange, the covered up layers incorporate layers that perform convolutions. Ordinarily this incorporates a layer that does duplication or other speck item, and its actuation work is commonly ReLU. Typically taken after by other convolution layers such as pooling layers, completely associated layers and normalization layers.

ADVANTAGES OF CNN

- It compared to its forerunners is that it naturally identifies the imperative highlights without any human supervision and CNN is additionally computationally efficient.
- Convolutional Neural Systems take advantage of local spatial coherence within the input (regularly pictures), which permit them to have less weights as a few parameters are shared.
- This handle, taking the shape of convolutions, makes them particularly well suited to extricate important information at a moo computational cost.
- Convolutional neural organize may be a course of profound learning strategies which has ended up overwhelming in different computer vision errands and is pulling in intrigued over a assortment of spaces, counting radiology.
- It has one or more convolutional layers and are utilized primarily for picture preparing, classification, division conjointly for other auto connected data.

OBJECTIVES

- To design and develop a quality analyzer for citrus fruits using sensor.
- To determine the quality parameters for various citrus fruits.
- To measure the pesticide residue and ripeness indices for the citrus fruits.

- To identify the detection of disease in citrus fruits.
- To do cost estimation for fabricated quality analzyer.
-

MATERIALS AND METHOD

MATERIALS

Lemon, Orange, Musambi were the sample used for trails to deduct the pesticide, ripeness level and early detection of citrus disease.The materials selected do not cause any mechanical damage. Many trials are conducted in the selection of materials. Also, the materials should have their own properties with high strength. The materials used for fabrication of this machine are:

- Node MCU
- ESP32
- OLED Display
- MQ-135
- MQ-6
- Thonny (Application Software)
- Arduino software
- Phython programming

METHODOLOGY

The design methodology involves the integration of MQ-135 and MQ-2 gas sensors with a NodeMCU (ESP8266) microcontroller to create a versatile gas detection and monitoring system. Capable of detecting various air pollutants and flammable gases, these sensors collect information about environmental conditions. The NodeMCU enables wireless connectivity, enabling real-time data transmission to a web platform or local display. In addition, the OLED screen provides a user-friendly interface for immediate delivery of information. The system uses data processing algorithms to analyze the gas concentration, which increases its efficiency. Calibration with standard gas concentrations ensures accuracy. Field testing confirms system performance in various environments. The holistic approach integrates sensor data into comprehensive gas monitoring, making it a powerful tool for applications such as air quality assessment or gas leak detection in both industry and households.

The project methodology focuses on the integration of MQ-135 and MQ-2 gas sensors into a NodeMCU (ESP8266) microcontroller with the aim of developing a versatile gas detection and monitoring system. Known for their ability to detect various air pollutants and flammable gases, these sensors are key data collection components. The NodeMCU microcontroller acts as a central device that facilitates wireless communication for real-time data transfer.

The implementation begins with the physical integration of the gas sensors into the NodeMCU microcontroller, which ensures smooth communication and data exchange. Sensors are strategically placed in the environment to efficiently collect the appropriate gas concentrations.

A NodeMCU microcontroller with Wi-Fi capabilities allows the collected data to be transferred to a network platform or local display device. This wireless feature ensures accessibility and real-timmonitoring of gas levels, improving system usability and efficiency.

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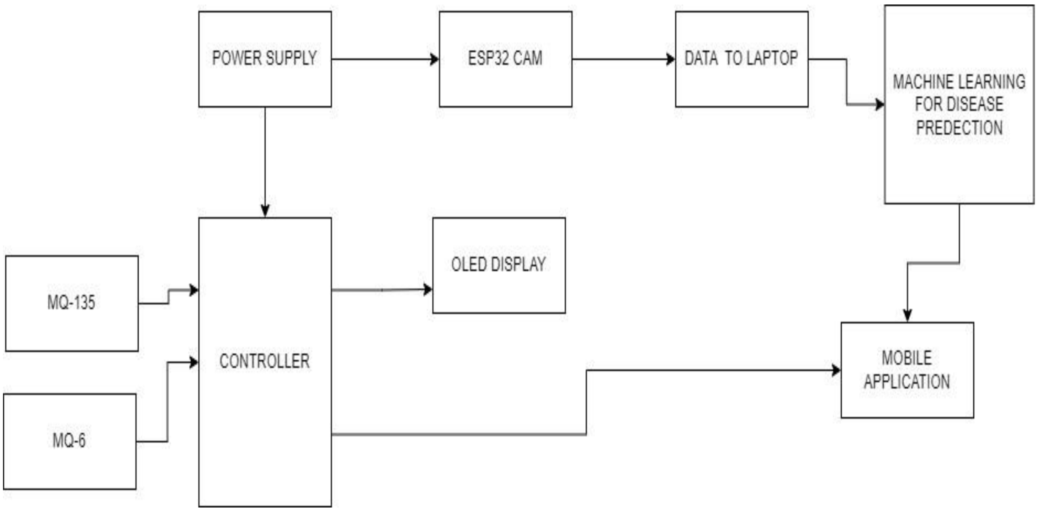

Figure 3.1 Methodology

The system includes an OLED display that provides a user-friendly interface for data visualization to provide immediate on-site information. This display facilitates rapid evaluation of gas concentrations without additional equipment or complicated setup.
In addition, the system uses advanced data algorithms to analyze gas concentration, which improves its efficiency and accuracy. To ensure reliability and accuracy of system measurements, calibration procedures are performed with standard gas concentrations.
Field testing plays a crucial role in validating system performance in various environments. Rigorous testing in various environments, including industrial and domestic environments, evaluates the efficiency and reliability of the system, ensuring its suitability for real applications.
The comprehensive approach used in this project integrates sensor data into comprehensive gas monitoring, making it a powerful tool for applications such as air quality assessment and gas leak detection. Whether used in industrial or residential applications, this system provides a robust solution for detecting and monitoring gas levels, increasing safety and environmental awareness.

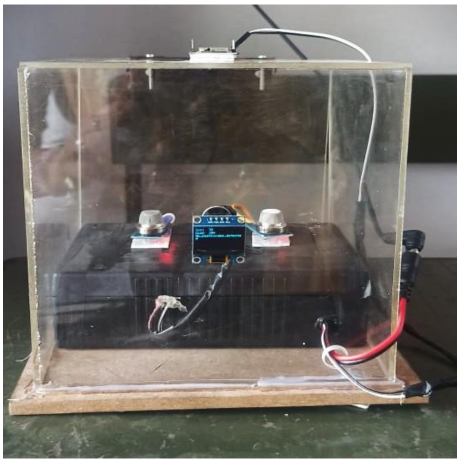

Figure 3.2 Working of Citrus fruit quality analyzer

Python Code with CNN and OpenCV
The Python code will be used to process the images captured by the ESP32CAM and detect the quality of the citrus fruits. It will use a CNN to classify the images as healthy or unhealthy, and OpenCV will be used to detect the affected

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percentage using contour detection.

IMAGE PROCESSING STEPS

- **Image Acquisition:** Capturing pictures of citrus fruit in computerized structure/digital form and stored in an advanced digital media.
- **Image Pre-processing:** Perform resizing of citrus fruits images to ensure consistency.
- **Segmentation:** Segmentation is utilized for partitioning and isolating an image into different parts which are desirable.
- **Feature Extraction:** Acquiring features like color tone, surface texture and shape
- **Image Characterization:** This part examines property of image features including organizing its data into categories.

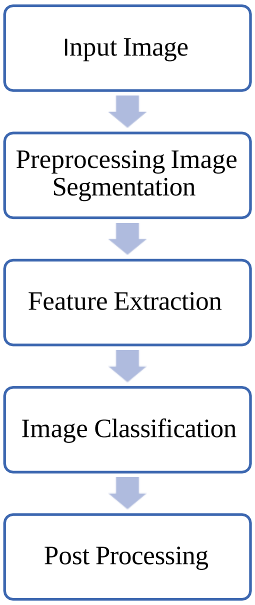

Figure 3.3Image Processing Steps Flow Chart

Thresholding is a type of image segmentation, where we change the pixels of an image to make the image easier to analyze. In thresholding, we convert an image from color or grayscale into a binary image, i.e., one that is simply black and white.

PROCEDURE FOR FABRICATION:

1. Connect the ESP32CAM module to your laptop via the USB cable.
2. Install the necessary software, including the Arduino IDE, Python 3.x, OpenCV library
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4. Connect the ESP32CAM module to your laptop via the USB cable.
5. Install the necessary software, including the Arduino IDE, Python 3.x, OpenCV library,.
6. Program the ESP32CAM module using the Arduino IDE and upload the code to the module. The code should capture images of citrus fruits and stream them to the laptop.
7. Write a Python code with a CNN and OpenCV to process the images captured by the ESP32CAM and detect the quality of the citrus fruits. The CNN should classify the images as healthy,scab,
8. Run the Python code and capture images of the citrus fruits using the ESP32CAM module.The detected data will be sent to Node MCU and displayed on the webpage.
9. Connect the MQ135 and MQ6 gas sensors to the NodeMCU board with correct cabling and connectors.
10. Calibrate the MQ135 and MQ6 sensors to accurately detect pesticide residue and ripeness levels. This entails exposing the sensors to known gas concentrations and changing their output accordingly.
11. Create Arduino code to read data from MQ135 and MQ6 sensors linked to the NodeMCU board. Convert analog

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sensor readings to digital values and send them serially to the attached laptop.

12. Write Python code to accept sensor data sent by the NodeMCU via serial connection and analyze the obtained data to extract useful information, such as gas concentrations and ripeness levels.

13. Analyze sensor data to detect the pesticide residue and maturity of citrus based on sensor data and recognized standards.

14. Use Python tools like thonny to display the pesticide residue and ripeness results on the laptop's screen.

15. Integrate the Arduino and Python code to provide smooth communication between the NodeMCU and the laptop and Validate the system's functionality by testing it with citrus fruits of varying ripeness and pesticide residue concentrations.

DETERMINATION OF PRECISION OF RESULT

Determination of Precision is done for checking the error percentage of the quality scanner which is done by placing the sample in container between two gas sensors and set of trails were taken and consistency is determined.

S.no	Sample	Pesticide residue percentage	Ripeness percentage	Presence of pesticide

Table 3.1 Determination Of Precision Of Result(Sample)

RESULT AND DISCUSSION

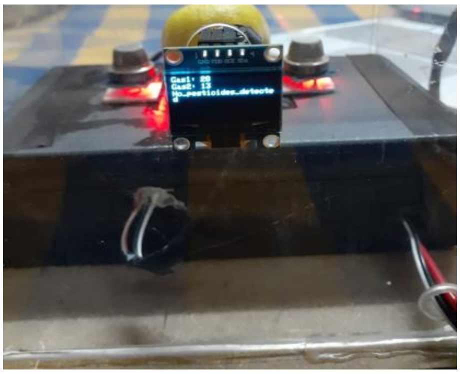

Fig 4.1 Machine Readings Of Citrus Fruit Quality Analyzer

S.no	Sample	Gas 1	Gas 2	Ripeness percentage	Presence of pesticide
1.	Lemon	44	76	79	Normal
2	Lemon	54	86	80.22	Normal
3	Musambi	105	143	80.92	Chlorpyrifos
4	Musambi	57	68	60	Normal
5	Orange	67	86	83.4	Normal
6	Orange	114	105	90	Chlorpyrifos

Table 4.1 Determination of precision of result

The system outputs a probability score indicating the likelihood of exceeding a safe pesticide residue limit. The gas sensor system detects pesticide residues in citrus fruits with excellent sensitivity and accuracy, producing findings equivalent to conventional laboratory procedures. The method showed promising accuracy in identifying pesticide residues and determining citrus fruit maturity levels. The challenges included calibrating sensors for accurate detection thresholds and dealing with ambient interferences. Calibration procedures and data filtering techniques were used to improve the accuracy and dependability.

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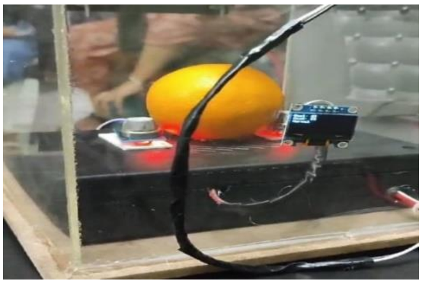

Fig4.2 Trials Taken

The MQ6 sensor accurately detects the maturity of citrus fruits, giving dependable data for harvest optimization. While the MQ135 demonstrated more sensitivity to pesticide residues, the MQ6 excelled in determining ripeness stages based on ethylene levels. Both sensors efficiently distinguished between different amounts of pesticide residues and ripeness stages, which improved the accuracy of our detection system.
The ESP32 camera accurately detects common citrus fruit illnesses in their early stages, allowing for prompt intervention and crop management. The ESP32 camera demonstrated efficacy in early disease detection in citrus fruits, providing high-resolution pictures for reliable analysis. Image processing methods contributed significantly to disease identification accuracy. However, constraints such as illumination differences and picture noise were discovered, necessitating more optimization for consistent performance.

CONCLUSION

The study concludes that the development and implementation of a gas detection and monitoring system integrating MQ-135 and MQ-2 gas sensors into a Node MCU microcontroller is a significant milestone in the field of environmental sensing technology. Thanks to a careful methodology that includes sensor integration, wireless connectivity, data processing algorithms and rigorous field testing, we have successfully created a versatile and reliable tool for gas detection in various environments. The system's ability to detect various air pollutants and flammable gases, along with its real-time monitoring capabilities and user-friendly interface, make it a valuable asset in various applications such as air quality assessment and gas leak detection in industry. and home settings. Going forward, further improvement and optimization of the system and continuous validation through extensive field testing will increase its effectiveness and increase its potential impact on safety, environmental awareness and public health. Thanks to the continuous development of sensor technology and data techniques, our gas detection and monitoring system demonstrates the potential of interdisciplinary innovation to solve pressing environmental problems and promote a safer and healthier future for communities around the world.

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