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DEVELOPMENT OF ADULTERATION DETECTOR FOR BLACK PEPPER USING IMAGE PROCESSING (CNN)

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ABSTRACT
Detecting adulteration in food products is crucial for ensuring consumer safety and maintaining quality standards. This project proposes a novel approach for pepper adulteration detection using ESP32-CAM, an integrated system combining hardware and software components. This system utilizes a Convolutional Neural Network (CNN) model trained on preprocessed pepper dataset to accurately identify adulteration. Additionally, we employ contour detection techniques to enhance the precision of our predictions. The project begins with the preprocessing of the pepper dataset, followed by training a CNN model to recognize adulteration patterns. This trained model is then integrated into the ESP32-CAM device, which is powered by a lithium battery for portability. The ESP32-CAM device connects to a local server, allowing it to stream live video for real-time analysis. During operation, the ESP32-CAM captures live video of pepper samples and sends it to the local server. The integrated CNN model and contour detection algorithms analyze the video feed to identify any signs of adulteration. System provides instant feedback, alerting users to potential adulteration in the pepper samples. This project offers a practical solution for detecting pepper adulteration in real-time, enabling consumers and authorities to take timely action to ensure food safety and quality. Moreover, the portability of the ESP32-CAM device makes it suitable for use in various settings, from agricultural farms to food processing facilities and retail outlets.

Keywords:
Spice, detection, adulteration, quality.

1.INTRODUCTION

Despite the fact that food adulteration, especially with regards to spices such as pepper. is a widespread and alarming problem in the world. Because of its widespread use and relatively high price, pepper, a spice known for boosting flavor, is often the target of adulteration. In order to boost profit margins or satisfy supply demands, adulteration entails the deliberate inclusion of less expensive alternatives or pollutants. This poses serious health concerns to consumers and erodes confidence in the food business. Even with strict standards and quality control procedures in place, adulteration is still a problem. This is caused by a number of things, including the financial incentives behind dishonest behavior, a lack of resources for oversight and punishment, and the ongoing development of sophisticated adulteration methods. As a result, customers are exposed to ingesting tainted goods, jeopardizing not just their culinary pleasure but also their health. We suggest a novel method for identifying pepper adulteration utilizing cutting-edge technical methods in response to this urgent problem. Our approach combines software and hardware elements to build a reliable and effective detection system that can quickly and reliably identify tampered pepper samples. The ESP32-CAM, a flexible microcontroller unit with a

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camera module that functions as the hardware platform for recording live video feed, is the central component of our methodology. To precisely analyze pepper samples, this device is paired with an advanced software architecture that incorporates contour detection techniques and a trained Convolutional Neural Network (CNN)model

2.PROBLEM STATEMENT

The adulteration of pepper poses complex problems that require creative fixes. The health risk that consumers face when consuming pepper goods that have been tampered with is one of the main worries. Adulterants can have negative consequences on human health, ranging from allergic reactions to serious illnesses. Examples of adulterants include sawdust, wheat, and even hazardous compounds like lead or pesticides. Additionally, adulteration undermines the originality and quality of pepper goods, undermining consumer confidence and harming the standing of respectable manufacturers. Conventional techniques, including chemical analysis or sensory evaluation, are labor-intensive, time-consuming, and need specific tools and knowledge to identify pepper adulteration. These techniques are not suitable for regular inspections and do not yield real-time data, which allows contaminated products to get into the market unnoticed. The worldwide structure of the food supply chain also makes identification more difficult because adulteration can happen at any point in the process, from distribution to farming. A comprehensive and proactive strategy combining technical innovation, regulatory enforcement, and consumer education is needed to address the issue of pepper adulteration. Our goal in creating a dependable and effective detection system is to enable all parties involved in the food supply chain to protect consumer health and adhere to industry requirements.

3.REVIEW OF LITERATURE

1. Title: Detection of Adulteration in Fruits Using Machine Learning
Publication: 2021 Sixth International Conference on Wireless Communications Signal
Processing and Networking (WiSPNET) Food is essential for life. The food we take should be pure, nutritious and free from any type of adulteration for proper maintenance of human health. In this paper, an IOT based food and formalin detection technique is developed to detect the presence of formalin using machine-learning approaches. Volatile compound HCHO gas sensor connected with Raspberry pi3 were used to extract the concentration of the formalin as a function of output voltage of any fruit or vegetable and different machine learning algorithms were used to classify the fruit or vegetable based on their extracted features. Supervised machine learning algorithms have been incorporated in our system to accurately predict the correct concentration of formalin at all temperatures which is also able to correctly classify between artificially added and naturally formed formalin.
2.Title: Detection of Food Adulteration using Arduino IDE
Authors: B. Perumal,Subash Balaji A,Vijaya Dharshini M,Aravind C,J. Deny,R
Rajasudharsan,
Publication: 2021 Second International Conference on Electronics and Sustainable
Communication Systems (ICESC)
To ensure proper hygiene and safe food quantity and quality, food quantity and quality should be examined and monitored on a regular basis. Some businesses can add The designed resonant sensor is fabricated on a 1.6 mm FR4 substrate. A sample
container made of borosilicate glass is specially designed to make the overall procedure
to be non-contacting and nondestructive. The fabricated sensor is finally tested for
detecting adulteration with different concentration levels in edible oils.
4.Title: Adulteration Detection of Grape Fruit Juice Using PCA and LDA Pattern
Recognition Technique
Authors: Hemanta Naskar,Vikas Nandeshwar,Siuli Das,
Publication: 2018 IEEE Applied Signal Processing Conference (ASPCON)
This study reports a Constant Phase Element (CPE) sensor of thin film coating of Poly Methyl Methacrylate (PMMA) to detect grape juice sample adulterated with sugar solution and water. The experimental data taken for analysis is constant phase data. The data analysis technique used is Principal Component Analysis (PCA), Box Plot & Linear Discriminant Analysis (LDA). The reported Separability index (SI) helps to distinguish different adulteration like sugar solution and water in pure grape juice. adulterants to food products to satiate the thirst of

selfishness, and make a lot of money by selling low-quality food at a higher price. Since human health cannot be compromised, a food adulteration monitoring system should be established to detect the presence of adulterants in food products. The proposed method is governed by Arduino, which regulates the use of sensors within the system. The recorded information will be transferred to the LCD digital display, which includes alphanumeric display module and therefore the result is displayed. With the employment of this technique, the consumption of poor-quality food will be avoided. Mostly, the simplicity of the system will facilitate everyone (consumers, food inspectors, etc.) to use the food adulteration observance system.

3.Title: Nondestructive technique for detection of adulteration in edible oils using planar RF sensor
Authors: Muhammed Shafi K.T.,Abhishek Kumar Jha,M. Jaleel Akhtar,
Publication: 2016 IEEE MTT-S International Microwave and RF Conference (IMaRC)
In this paper, a non destructive technique is presented for detection of adulteration in common edible oils using the proposed microwave planar resonant sensor. The proposed sensor is operating in the ISM (industrial, scientific and medical) frequency band of 5.85 GHz. The sensor is designed using the full wave electromagnetic solver, the CST Microwave Studio, and an empirical model of the proposed sensor is developed for the accurate calculation of complex permittivity of standard edible oil samples under test in terms of the resonant frequency under loaded condition. The developed model is then used to detect the percentage adulteration of contaminants in the pure edible oil samples.

4.METHODOLOGY

4.1 Integration of Components

The process starts with the combination of software and hardware elements to build a strong pepper adulteration detecting system. A learned Convolutional Neural Network (CNN) model, a local server, and the ESP32-CAM microcontroller unit are the essential parts. The hardware platform used to record a live video stream of pepper samples is the ESP32-CAM. It has a camera module installed and set up to send video data for analysis to the nearby server. The software interfaces and algorithms required to interpret the video feed and execute the CNN model are hosted on the local server. Based on visual signals taken from the live video feed, the trained CNN model—which has been optimized for pepper adulteration detection—classifies the pepper samples as real or adulterated. The smooth communication and cooperation between hardware and software components made possible by their integration allows for the very accurate and efficient real-time detection of pepper adulteration.

4.2 Specifications

It is crucial to identify the system's needs and specifications before moving further with the technique. This entails figuring out the technical details of the hardware components, like the camera module's resolution and rate, the ESP32-CAM's processing power and memory capacity, and the local server's connectivity options, in addition to the performance metrics, like detection accuracy, processing speed, and scalability. It is also necessary to take into account the deployment environment and operating circumstances, including illumination, humidity, temperature, and power supply needs. The development process can be efficiently directed by creating precise specifications up Front , guaranteeing that the finished system satisfies the necessary operational requirements and performance standards.

4.3 CNN ALGORITHM

4.3.1 Preprocessing

Preparing the input data for the CNN model's training is the preprocessing step. To improve the model's robustness and generalizability, this entails gathering a varied collection of pepper photos, classifying the images as real or fake, and using data augmentation approaches. Rotation, scaling, flipping, and adding noise are examples of data augmentation techniques that are used to create more training samples and add diversity to the dataset. This enhances the model's capacity to generalize to new data and helps avoid overfitting. In order to guarantee uniformity in the input data, the photos are additionally preprocessed to standardize their size, color, and orientation. This preparation stage gets the dataset ready for efficient CNN model training.

4.3.2 Training

The CNN model gains the ability to accurately identify whether the pepper samples are real or tampered with during training by extracting pertinent features from the input photos. The training procedure is carried out

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repeatedly until the model performs satisfactorily on the validation dataset, signifying that it has developed strong generalization skills to new data.

4.3.3 Testing Using ESP32-CAM
The CNN model is embedded into the ESP32-CAM device allowing real-time testing and deployment after it has been trained and verified. Pepper samples are captured in real time by the ESP32-CAM, which then feeds the footage to a local server for analysis. After being trained, the CNN model is executed locally by the server. It analyzes the video stream and uses its visual characteristics to determine whether the pepper samples are real or fake. During the testing phase, the effectiveness of the system in identifying pepper adulteration is assessed under a range of circumstances, including variations in illumination, angles, and distances. To evaluate the efficacy and dependability of the system, performance measures like processing speed, false positive rate, and detection accuracy are examined. Any potential flaws or areas for development can be found and fixed by testing the system with actual pepper samples and circumstances. This guarantees that the finished product satisfies the operational requirements and intended performance standards.

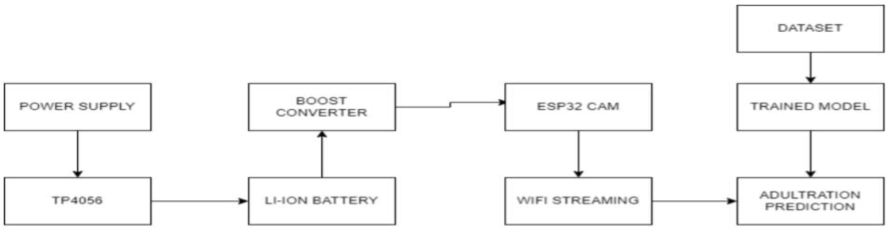

Figure 1: block diagram

4.4 Proposed Methodology
4.4.1. Integration of ESP32CAM
Put the ESP32-CAM, trigger button, and suitable power supply together to assemble the gadget. Create firmware that will take crisp pictures when a button is pressed.
4.4.2 Information Gathering
Assemble a varied collection of pictures showing pure and tampered spices. For a strong dataset, take into account changes in illumination, angle, and background.
4.4.3Transfer of Data
Create a safe route of communication between the central system and the gadget .Protocols such as MQTT or HTTP can be used to send taken photos quickly.
4.4.4 Visual Compositing
Utilize OpenCV image processing algorithms to improve acquired images.Put into practice the region of interest identification and feature extraction methods.
4.4.5.CNN Model Development
Create an architecture for a Convolutional Neural Network that is appropriate for classifying adulterated spices. Divide the dataset into sets for testing and training.

4.4.6 Training Models
Utilizing the training dataset, train the CNN model. For the best performance, adjust the hyperparameters. To make sure the model is generalizable, validate it using the testing dataset.
4.4.7Classification of Adulterations
Include the trained CNN model in the main classification system for real-time. Use algorithms to analyze the model's output and calculate the degree of adulteration.
4.4.8 Presentation of Results
Create an intuitive user interface to show the classification findings.Provide reports or visual cues to illustrate the level of adulteration found.
4.4.9 Evaluation and Enhancement

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Verify the robustness of the system by doing extensive testing in a range of scenarios .For increased precision and effectiveness, optimize parameters and algorithms.

5.HARDWARE DESCRIPTION

5.2.1 ESP32CAM Module

The ESP32-CAM is a small, low-power camera module built on the ESP32 platform. It has an OV2640 camera and an inbuilt TF card slot. The ESP32-CAM can be extensively utilized for intelligent Internet of Things applications such as wireless video monitoring, QR identification, image uploading over Wi-Fi,
and more.

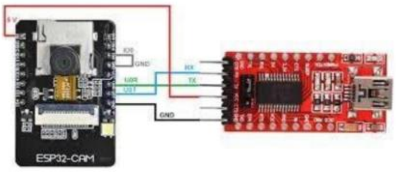

Figure 2: ESP32 CAM

5.2 Lithium Ion Battery

Lithium ions serve as the main electrolyte component in lithium-ion batteries, particular kind of rechargeable battery. Lithium atoms in the anode become ionized and lose their electrons during the discharge cycle. When the lithium ions reach the cathode, they recombine with their electrons and electrically neutralize after moving from the anode and through the electrolyte.

Figure 3: lithium ion battery

4.Tp-4056 Charging Processor

For single cell lithium-ion batteries, the TP4056 is a full linear charger with constant voltage and current. The TP4056 is a perfect fit for portable applications because to its SOP packaging and minimal number of external components. Moreover, the TP4056 is compatible with wall adapters and USB

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Figure 5: charging processor

6.NODEMCU Uno Board

The various parts of the NODEMCU board will be explained to us. Since the NODEMCU UNO board is the most widely used member of the NODEMCU board family, we shall examine it. It's also the greatest board for beginners to learn electronics and coding. While certain boards may differ somewhat from the one shown in the majority of these components are shared by most NODEMCUs.
NODEMCU board can be powered by using the USB cable from computer

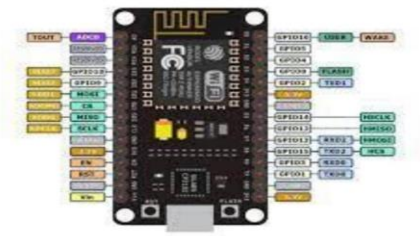

Figure 5.4 NODEMCU Board

SOFTWARE DESCRIPTION

PYTHON:

PYTHON 3.7:

Python is a high-level, general-purpose programming language that interprets code. Python was developed by Guido van Rossum and was originally made available in 1991. Its design philosophy places a strong emphasis on code readability and makes extensive use of whitespace. Python is a robust and simple-to-learn programming language. Its object-oriented programming methodology is straightforward but efficient, and its high-level data structures are efficient. Python is a free and open-source programming language that is perfect for scripting and quick application development on a variety of platforms. Its beautiful syntax and dynamic typing further enhance its appeal. Along with supplementary documentation, the same website hosts distributions of numerous free third-party Python modules, tools, and programs. It is simple to add new functions and data types to the Python interpreter that are implemented in C or C++ (or other languages that may be called from C). Python can also be used as an extension language to create programs that can be customized. The reader is given an informal introduction to the fundamental ideas and functionalities of the Python language and system in this lesson. For practical experience, it's helpful to have a Python interpreter on hand; but, since all examples are self-contained, the lesson can also be read offline. See library-index for a description of standard objects and modules. A more formal definition of the language can be found in the Reference-index. Read extending-index and c-api-index before writing any extensions in C or C++. Python is also thoroughly covered in a number of books. It is not the goal of this tutorial to be all-inclusive and cover every feature—or even every feature that is frequently utilized. Rather, it provides an overview of numerous noteworthy elements of Python and helps you understand its style and taste. You will be able to read and create Python programs and modules after finishing

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it, and you will be prepared to study more about the many Python library modules that are covered in library-index.

6.2 THONNY IDE

Thonny is an Integrated Development Environment that is lightweight and malleable. It was created to offer a quick and compact IDE with minimal dependencies on other software. Another objective was to minimize dependence on a certain desktop environment, such as KDE or GNOME. As a result, Thonny just needs the GTK2 toolkit, and installing the GTK2 runtime libraries is all that's needed to run it. You will need the GTK (>= 2.6.0) libraries and header files in order to compile Thonny yourself. The Pango, Glib, and ATK header files are also required. You may get all of these files at http://www.gtk.org. Naturally, you also need the Make tool and a C compiler; the supplied Scintilla library also requires a C++ compiler. The GNU versions of these tools are recommended.

7.RESULTS AND DISCUSSION

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7.1 Pepper from market (Detection)

Figure 7.1.1

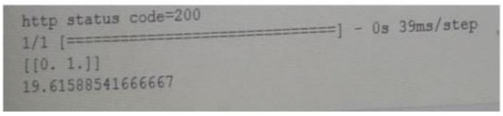

Figure 7.1.2

Sample taken	In grams	Adulteration percentage
Only pepper	10g	19.41%

Table 7.2

7.2 Papaya Seeds only (Detection)

Sample taken	In grams	Adulteration percentage
only papaya seeds	10g	95.96%

Table 7.2

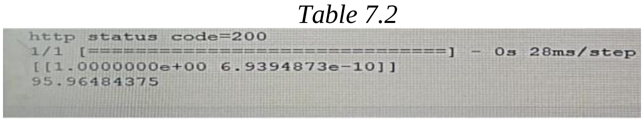

Figure 7.2.1

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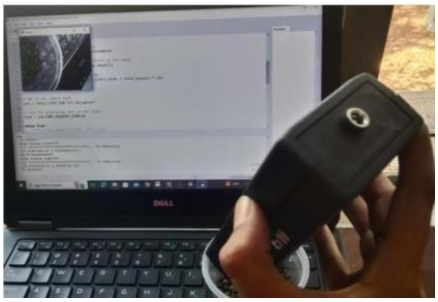

Figure 7.2.2

7.3 Pepper adultered with Papaya Seeds (Detection)

Figure 7.3.1

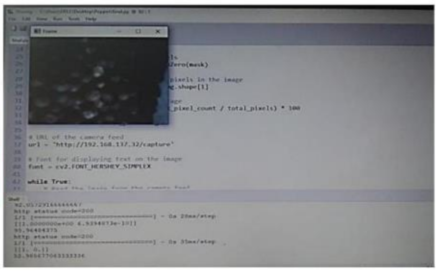

Figure 7.3.2

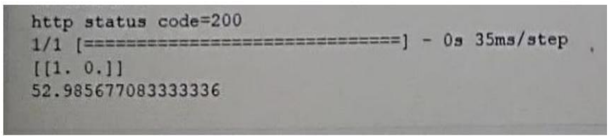

Figure 7.3.3

Sample taken	In grams	Adulteration percentage
Adulterated pepper	6g(pepper&4g papaya seeds)	52.98%

Table 7.3

CONCLUSION

The methodology describes a thorough process for utilizing ESP32-CAM in conjunction with a Convolutional Neural Network (CNN) model that has been trained to detect pepper adulteration. We have created a reliable and effective solution for preserving industry standards in the spice business and protecting consumer health by integrating hardware and software components with ease, preprocessing the data, training the CNN model, and testing the system with real-world samples. By detecting and accurately classifying contaminated pepper samples in real-time, our technology provides a practical and economical way to guarantee the authenticity and purity of pepper products, which in turn boosts consumer confidence in the food supply chain. Future research and development could focus on a number of areas to improve the functionality and suitability of our pepper adulteration detection system. First off, further refinement of the CNN model and investigation of cutting-edge

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deep learning methods may enhance the efficacy and precision of adulteration detection, particularly in cases that are delicate or intricate. Furthermore, the ESP32-CAM device's detection range may be expanded beyond visual cues by integrating further sensors or analytical techniques, allowing for multi-modal study of pepper samples. Additionally, working together with industry stakeholders and regulatory bodies may make it easier to implement our method in practical contexts and aid in large-scale initiatives to combat adulteration. We can improve food safety and help build a more dependable and transparent food supply chain by keeping up our innovative and cooperative efforts.

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