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

FOOD ADULTERATION DETECTOR USING IMAGE PROCESSING AND CNN

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***Abstract*:** Food adulteration on a holistic approach is jeopardizing consumer food safety and health. Leveraging the vision of low power AI with computer vision and deep machine learning techniques such as CNN and image processing, this paper gives a comprehensive review on all these aspects related to the efficient and precise identification of the foreign particles and the adulterated food materials [1]. This review delves more into the percentage of food adulteration which includes contamination and the amount of adulterant mixed with food products emphazing the threats or the risks involved. This paper also dwells more on image processing, image segmentation, feature extraction using CNN algorithms which is executed by Jupyter Python Notebook. It explains more on high performing CNN models for developing a food adulteration detection system.

Keywords: Image Processing, CNN models, adulteration, image segmentation, GPU

I. INTRODUCTION

Food adulteration has always been a concern in the market domain especially in hotel industries. It is a persistent problem that is prevailing since ages. The quality of food products has been deteriorating and involves the addition of foreign contaminants and the harmful substances added as food additives [1]. Prevention is better than cure is a phrase that is always used prevalently so prevention of food safety and public health is very important. In Gen-z, people have come up with newer innovations and ideas related to image processing to maintain the quality of food and maintain consumer trust [2]. In recent coming years, image processing has turned out to be a vital source for DSP applications and it is combined with Convolutional Neural Networking models which is a main algorithm also used in deep machine learning techniques which becomes easier.

The cumulative integration of IOT, image processing and convolutional neural network shall be discussed in this review. These have several advantages which enables to extract the right amount of adulterants or the poisonous sweeteners/materials that are added to enhance or garnish the food. Image process techniques enable preprocessing, filtering the food images and amplifying it eliminating the discriminative capabilities in a system analysis. These deep machine learning algorithms comes up with enhancing knowledge towards learning complex and rigid patterns from large scale datasets such as VGGnet making it easier to classify and separate out adulterated products [4]. In addition to this this paper also dives into the challenges and certain prerequisite limitations related to image based food adulteration detection system. Involving IOT and cloud data for uploading all the parameters such as appearance, smell, texture, taste of food are displayed. Web development is done through HTML, CSS and JavaScript with all the parameters being monitored real time.

These techniques include the usage of conveyor belt that is used to shift food items from one part of the region to the other part of the region using motor and gears. It is linked with IOT and the controlling of belt is done when the code is loaded to the microcontroller Arduino UNO to stop the running of the belt when it observes that food is getting loaded in the belt. To prevent the overflow placing of IR sensors is done to detect the motion or the presence of the object.

II. TYPES OF FOOD ADULTERATION

Several researchers have mentioned the real-time application related to machine learning techniques for the detection of food adulterants. Some of the notable types of food adulteration techniques are substitution, contamination, adulterate addition and mislabeling [1].

A. Substitution in food products

This process involves replacing a good ingredient food product with a very low quality alternative food product. If you take an example of an adulterated apple [4], they add shiny material to enhance the appearance and color and replacing it with a normal red apple and even sometimes edible oils are replaced with the adulterated edible oils [2]. CNN can detect and analyze the characteristics such as food texture, taste, smell identify and segregates the right characteristics of food product.

These methods have quite few several sub techniques to distinguish the adulterated products into different sections according to the ingredient, material and color used for food products.

Ingredient substitution uses a cheaper material that is utilized as a substitute for the initial ingredient [8]. For example, when we use vegetable oil rather than olive oil, or just adding certain fillers like sawdust or starch to ground flavors.

Species substitution is a part of substitution which is sort of adulteration that includes supplanting a costlier or alluring species of an ingredient with a cheaper or second rate one [6]. For occurrence, substituting a premium angle species with a cheaper variety or utilizing horse meat rather than meat.

Adulterant substitution Adulterants are those substances that are included for nourishment to extend its amount or improve its appearance. Substitution occurs when a distinctive adulterant is utilized instead of the regular one [7]. For illustration, utilizing manufactured colors rather than normal ones, or including melamine to drain to extend its protein substance.

B. Contamination in food products

Contamination is a process where there is a wide inclusive nourishment of adulteration which includes the presence of contaminants/ artificial additives at a large scale. These products have contamination where in it can happen due to many different factors dealing with capacity, natural conditions and handling of adulterants. This defilement can have fatal or extreme health results on the customers.

Biological contamination happens when there are nourishment items contaminated with very destructive microorganisms that includes fungi, parasites and other microbes [4]. Common microbial names are E. Coli, Salmonella that could lead to infections and other diseases.

Chemical contamination enters through nourishment products through various other sources like insectides, pesticides, artificial additives, liquid paraffin (wax) which are added to substances [5]. For instance, pesticide residues are added to fresh products such as apple and coating of wax can be observed for garnishing purposes or contamination of seafood, fishes with mercury and lead.

Physical contamination are very remote objects that enters adherently into food chain during handling and bundling process [3]. Some of the physical contaminants include metal parts, hair, insect and other minute particles that might hamper the food causing many infections and diseases that might be fatal and quite deadly to the mankind.

C. Dilution and adulteration

Dilution is yet another common practice of food adulteration. This is done by diluting the food by giving external nourishment item that is rated as a second rate cheap substance [2]. These practices are meant to extend the amount of tem thereby decreasing the quality of food.

Water dilution method allows including water or any other food item which is a common strategy for dilution in food products. For instance, including alcohol in Appy fizz and certain amount of water to natural fresh juices to increase the volume and sell it to customers at a very high rate.

Filler dilution is a very rare sight in food industry but very prominent in restopubs or breweries where it is used to add nourishment where bulking specialists are involved to extend the volume and quantity of food. For instance, adding soda to dosa batter fills our stomach very easily that has no dietary value.

D. Mislabeling in food packets

It is a form of nourishment pattern that mainly includes wrong or any misleading data or any other name given to a particular food item that actually doesn't have the relevant food matter [3]. This is actually pricely trick that can actually deceive or give wrong information to customers to woe them around the quality, ingredients, nature and the dietary value of the given items.

False ingredients happen when an item is labelled with ingredients that are actually not added neither present in the food product. For instance, labelling an item as "99.9% pure oil" but reality speaks volume where oil contains large amounts of petroleum oil and blend of oils and utilizing the manufactured flavors from the normal ones.

Allergen mislabeling also happens when an item fails to announce the minute presence of certain allergenic substances such as wheat, shellfish and peanut. This might cause certain infections and food poisoning and people with sensitivities who depends on labelling to dodge certain allergens. Fig 1(a) shows different types of food adulteration techniques explained in brief

Fig 1(a): Different types of food adulteration

III. TRADITIONAL METHODS FOR FOOD ADULTERATION

Adulteration with certain preservatives, artificial additives, sweeteners are used as common food adulteration techniques. Falsification of food materials is also labelled as food adulteration that also includes false claim for superior origin of products.

A. Sensory Evaluation

It is one of the most traditional practices or strategy that is utilized to mainly identify the nourishment of food items that are contaminated which is depended on human faculties of taste, smell, sight and other sensory parts [3]. These sensory specialists actually assess and senses the physical parameters to distinguish any deviations from the expected qualities that is used to demonstrate adulteration.

Sight /Visual examination of food products plays a very important role in identifying change in color, appearance and surface of the matter present outside. We can also detect if there is any insect or any other anomalous surface in the food product. Smell and taste are other sensory parameters that are some of the traditional practices to determine the contaminants in food.

B. Chemical Analysis

Chemical analysis is a very commonly used strategy worldwide for recognizing some of the food additives. These techniques include the utilization of different chemical tests which are used to differentiate the nearness of adulterants.

Polymerase Chain Reaction(PCR) is a chemical test technique that could be used as an atomic science strategy which is used to utilize and identify certain DNA arrangements of genetically modified plants that are used for production of food [5].

C. Microscopic Examination

Microscopic examination is a conventional strategy which is utilized for very minute microscopic detailing of food products for testing adulteration. It includes utilization of a microscope to visually look into the nourishment pattern of food items at a microscopic level. It allows identification of certain impurities that will be detected and will be displayed in the sample.

Foreign matter identification helps in microscopic examination that makes a slight difference in differentiating fragments, shape, spores, hair or other contaminants that cannot display within the nourishment item.

Sample preparation is a major step in microscopic examination where food samples are prepared before microscopic examination. This shall include homogenization, dilution and staining processes and then it is mounted on a microscope for testing and observation of contaminants.

Microscopic selection is an alternative method where the requirements of the analysis are shortlisted, according to that microscopes are used. Light microscopes, stereo microscopes and polarizing microscopes are some of the microscopes that are generally used for examining food adulteration.

D. Chromatography methods

These methods are implemented when they are broadly used only for detection of adulterants through color gradient methods. These include the examination, division and permission for identification and assessing the contaminants or the adulterants.

Gas chromatography is a procedure utilized to isolate unstable materials while testing. It is a common practice to distinguish pesticide residues and very unstable volatile compounds. It helps to recognize the nearness of certain volatile adulterants that float on the surface which is removed by gas particles.

Liquid chromatography is a much flexible technique in chromatography that can analyze and separate a good range of chemical food adulterants mixtures during the process. High performance liquid chromatography (HPLC) and Ultra-High Performance Liquid chromatography (UHPLC) are some of common methods used in adulteration too. They can easily distinguish viscous liquids from the dense ones. For instance, separating additives, mycotoxins, and some microbes.

E. Organoleptic Assessment

It involves using human senses (smell, touch) and other parameters to evaluate the quality of certain food products. It completely relies on certain sensory normality. It detects any changes in the food and taste variations, acidity, rancidity.

Considering the methods that are traditional, it provides indications of contaminants while they certainly have certain limitations. They might not be very accurate and precise in their results but still has the ability to detect sophisticated techniques which are implemented. Modern techniques include DNA testing, spectroscopy, immunoassays and case cluster. These methods are mostly

comprehensive and provides a deep insight towards diminishing food adulteration in the society thereby reducing diseases.

These techniques are important to note that the microscopic examination requires a well-known expertise in sample preparation, microscopy and interpretation of observed traits. Food scientists, micro analysts, forensic officers are also involved in all these while conducting the examinations regarding food adulteration.

IV. IMAGE PROCESSING TECHNIQUES

Image processing methods are sometimes considered crucial in DSP and other applications. They play a vital role in analyzing and detecting food related images by extracting information from the user. These methods help us to analyze the anomalies of food adulterants with many parameters.

A. Image acquisition and pre-processing method

In this particular stage this process involves mainly capturing food images which are of highest quality through web camera or ESP-32cam module. Image gets acquisited into different processes such as binaryzation, inverse filtering and then gets amplified with a predefined output [1]. Pre-processing methods involves variety of sub-methods such as image resizing, large noise reduction using an amplifier color detection using HSV values and binaryzation to get consistent quality food images without any errors or inconsistencies [2]. This happens in various stages with subsequent analysis.

B. Image segmentation technique

This is the second stage of image processing where images are partitioned into meaningful objects based on the test patterns and its characteristics such as taste, smell, appearance and the intensity of the color based on HSV-color space. Segmentation can also help in isolating or barring specific region of interest that includes foreign particles, food adulterants. It has algorithms such as grayscale imaging, Threshold imaging, selective blurring, clustering and other region-specific image processing methods which helps in getting the relevant and appropriate food images of the finest quality [3]. Fig 2(a) shows the basic block diagram of image processing process.

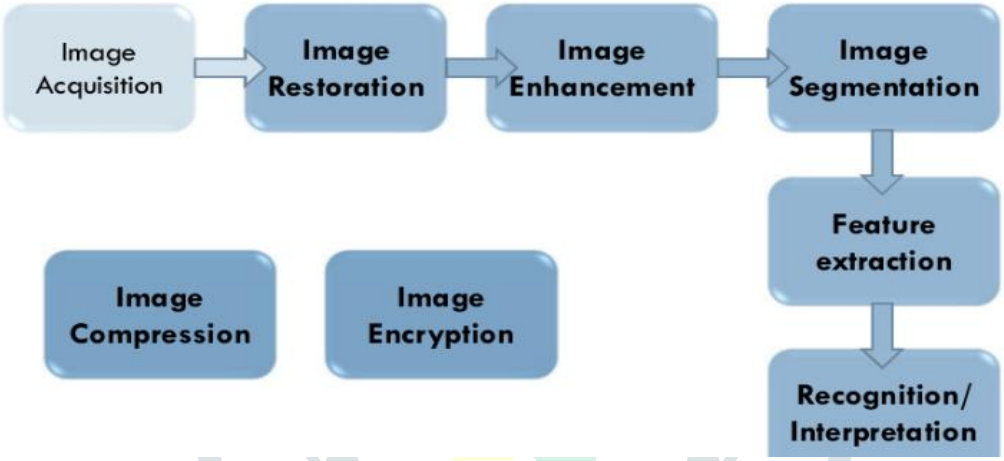

Fig 2(a): Block-Diagram of Image processing

C. Feature Extraction

This is the penultimate stage where the main aim is to capture very discriminative and clearer distinctive food images. These traits include color description, test pattern, color histograms and shape descriptors that includes Fourier and contour-based features [4]. It has a combination of all these features. These features which are obtained after classifying them are served as an input for classification based algorithms which is further used for sampling, analysis and proper identification of contaminated food samples.

D. Texture Analysis

This technique mainly focusses on finding the information which is related to the spatial arrangement of images based on pixels. Features that are implemented in this process are wavelet transforms, local binary patterns, gray level occurrence which are later computed to identify and characterize as well segregate the different textual traits of variety of food images. This analysis helps to identify minute subtle changes or some irregularities in the function which may depict food adulteration such as adding ajino moto coloring to food samples [5].

E. Pattern recognition

After obtaining the appropriate food images pattern recognition which is actually used to distinguish the difference between pure food samples and the adulterated food samples. Deep machine learning techniques such as CNN, VGGNet are applied using Jupyter python notebook which supports vector machine and later used for labelling datasets to understand the underlying food pattern which is adulterated [4]. Now these food samples are sent to the last stage, i.e.: Image enhancement for obtaining the final high quality image.

F. Image Enhancement method

This is the final stage where the images are enhanced with the aim to improve the quality of food images by restricting noise and enhancing brightness and contrast with the appropriate and adjustable sharpness and shadow. These include adaptive filtering method, histogram equalization which can actually show the percentage of adulterants by CNN algorithms making it more distinguishable from the proper food products [7]. It is also very important to know that the combination of all these methods of

image processing depends on the prerequisite requirements of the food adulteration detection work.

V. CONVOLUTIONAL NEURAL NETWORKS METHODS

These networks have a very broad networking and revolutionized view in the field of AI powered computer vision which includes detection and image classification of food adulteration techniques [7]. By providing a provision of leveraging their ability for finding test patterns and intricate patterns. This review provides more complicated view for CNN architecture which are to disseminate food contaminants.

A. Training Datasets

Training neural networks for food image extraction, image classification which involves a very detailed process to optimize the performance of datasets and achieve very precise best classification results. It begins with dataset collection, dataset preparation which involves a diverse and very vibrant dataset of food images with corresponding labels whether there is presence or absence of food contaminants [2]. This dataset is taken and then split into training, testing sets, aggregation sets and validation which ensures a good evaluation of provided network.

B. Transfer learning and fine-tuning approach

These both techniques are very powerful approaches in CNN for very food image processing methods. These methods help in leveraging trained models which are implemented on a large scale dataset that includes VGGNet, ImageNet [3]. These methods help in utilizing knowledge on a source task on CNN architecture.

Fine-tuning approach that goes beyond replacing later layers also updating the weights of layers which are retained. This model adapts more flexibly which shifted from target task to capture task specific methods. This step involves drastic changes to very early layers allowing that model to specialize into a very fine tuned dataset. Fig 3(a) shows transfer learning machine learning models.

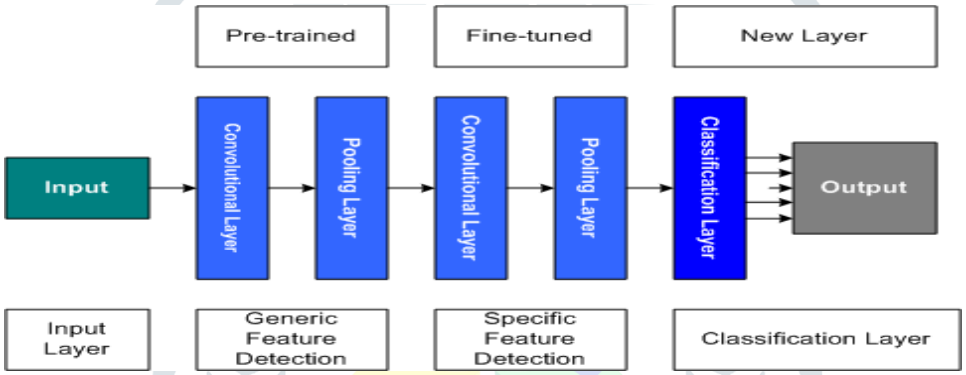

Fig 3(a): Transfer learning machine learning models.

C. Model evaluation metrics

It helps in assessment which plays a crucial role in assessing and reliability of Convolutional Neural Networks. These metrics always provides qualitative and quantitative approach of the model's precision, performance and accuracy in detecting the adulteration in food [4]. This evaluation helps researches to gain more insights in the world of model's strength.

Proportion of correctly classified colored food samples in the dataset must be very accurate. Precision plays a very important role in picking up appropriate food samples. It is always very important in food adulteration detection to minimize/reduce false positives making it a point that non-adulterated samples are not classified as adulterated food samples.

Receiver Operating Characteristic(ROC) curves are plotted that positive rate at various classification threshold techniques [8]. These representation offers a very fine graphical representation of model's various parameters, performance that determines optimal threshold value.

D. Data Augmentation

This technique in image processing and classification plays a very major important role in improving the dataset performance of Convolutional Neural Networks (CNN) [6]. This involves artificially augmented techniques that is used for training data sets by introducing various variations to food images.

Rotating augmentation method by various degrees helps the model to recognize the test patterns from various different angles for food adulteration. This technique identifies food contaminants with respect to the orientation of food samples.

Translation method in data augmentation helps in shifting images vertically and horizontally positional variations of translated food images. It is more robust to detect the changes in food position images that helps to detect the contaminants or adulterants. This pattern of test pattern images helps in enabling the datasets to detect adulterants through all these algorithms.

Flipping method creates additional instances of different orientation of food images. This augmentation technique helps in enhancing the quality of model's ability [7]. This method also recognizes the adulteration and contaminants mixed tie: Ajino moto or any sweeteners added making it more versatile to detect all steps to include that an adulterant is added or not irrespective of any orientation.

VI. Results and Discussions

After applying all the traditional methods for food adulteration to ensure that the food produced is safe, hygienic we have to carry out some formulations and tabulate all the contaminants and segregate them into different categories according to CNN algorithms and image processing processes [1]. This is done to potentially identify the hazards and other diseases caused by not taking the corrective action to mitigate them. We will observe and calculate the coefficients and correlate them between the chemical composition of the food material and quality and material of the food [8]. Table I illustrates the objective, techniques and samples obtained by food images from adulterated food products

Objective	Techniques	Samples
Detection of adulteration in goat milk vs camel milk	Multi variant analysis and other DSP techniques	Camel milk sample(1 litre)
Edible oils(Adulteration of a paraffin)	Fourier transform technique and image recognition method	Edible oils
Sugar adulteration in green and black tea	Spectral imaging technique	Green tea
Detection of adulteration in yogurt(curd)	Microbial and spectral analysis	Yogurt (30%)
Identifying pebble and sediment particles in rice bag	Sedimentation and spectroscopy	Rice Bag filled with rice(75%)

Table I: Samples of Adulterated products

VII. Conclusion

This is a promising approach that involves various processes like image processing, IOT, CNN techniques and various other algorithms for the sake of food safety system which contributes significantly in determining the percentage of adulteration in the products. Moreover, these technologies are still existent in today's world.

By leveraging the capabilities of deep machine learning algorithms which are well suited for segregating food images, it becomes easy to analyze the phonetical characteristics. The main part of image processing is that it enhances the visual quality of food images so that it becomes easier to segregate the adulterated food products.

Firstly, the usage of VGGnet, and other CNN algorithms are cost-effective and doesn't involve much integration of hardware integration. It is non-invasive and non-destructive technique which holds food integrity and other utilities.

The availability of diverse training datasets is a major challenge which is fulfilled by CNN algorithms and counter protected by image processing methods to ensure there is no static errors.

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