Grit Detection in Sustenance

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Abstract— Grit in sustenance is a matter of concern in food production that determines the safety and quality of food. Grits mainly include fruit stalks in dried fruits, bone fragments in meat products, glass, metal, rubber, insects in vegetables, wasps and fruit flies, and cod worm in fish, etc. If the food consisting of grit is accidentally consumed, then it leads to anxiety as it is hazardous. Therefore, the detection of grit in sustenance is essentially required. Active contour is one of the active models in segmentation techniques, which makes use of the energy constraints and forces in the image for the separation of the region of interest. This paper includes various techniques like X-ray, U-NET-based, thermal imaging, hyper spectral imaging, Terahertz, and ultrasonic Imaging, The main aim of the model is to homogenize regions in the image that belongs to the sustenance and enhance contrast where grit is present. This paper reviews grit detection in food by utilizing DEXA images in the contour algorithm.

Keywords— *CNN, VGG16, Deep learning, Convolution.*

I. INTRODUCTION

Recently, consumers have paid attention to quality and safety in their decision to purchase food products [1]. However, grits which are not normal food ingredients are unintentionally incorporated into the food during processing. These should be eliminated as a hazard to quality or safety. It is important to find a fast, non-destructive, and accurate detection technique for grits in the food processing industry [2].

In general, foods differ in internal structure and taste. The risk level foreign body depends on the size, type, hardness, and sharpness of the object [3]. Evaluating food requires checking the quality of each sample to reduce harmful intake and waste. Food control plays an important role, as health risks mainly depend on the food we consume. Humans can also do this food inspection manually, but this is limited to a certain amount. Because doing so many tests can pose minor health risks to your eyes. However, the production speed of the output is also different when compared with the food processing in the factor.

The main objective of the food processing industry is to supply products completely free from Grits, in order to meet the consumer's expectations [4]. It has been considered a serious offense for food manufacturers to carelessly fail to detect the presence of foreign bodies inside their food products. The economic justification for addressing these as serious issues arises from the need to protect a brand name, whether it's the brand of the manufacturer or of the retailer. Rather than the brand being damaged by a spate of consumer complaints, the reaction is usually to recall the product that might be affected. If the foreign body and its source can be identified and traced to a source in the supply chain, the depth and breadth of the recall can be limited [5]. Food manufacturers will perform several investigations at every line of operation, starting from the collection of the raw materials until the delivery process to determine whether it is a foreign body or not [6-7].

Besides, the food products should be kept and placed in a safe and clean environment as well as maintained at a suitable temperature to ensure insects or pests are not attracted. In the delivery unit, the transportation storage system plays a vital role in ensuring that the product is distributed safely to retailers and shops. Several issues of concern such as the storage temperature level for the asportation, cleanliness, and time span for delivering the product. This precautionary measure may minimize the probability of the food product being contaminated. There are also cases where surgery was required to remove the foreign body as reported [8-10]. Such cases may result in the food manufacturer losing customers' trust and incurring significant losses.

Early detection of grits is an important control measure in ensuring the safety and quality of food products [11]. The food industry makes numerous efforts to avoid unwanted grit objects in food. The conventional methods that have been used to detect foreign bodies include metal detectors, magnets, electrical impedance, and surface penetrating radar. Although these methods are simple and reliable, their weaknesses have restricted their applications [12]. Nonconductive materials such as plastic and glass cannot be detected using a metal and magnet detection system. Electrical impedance and surface penetrating radar do not work well with metallic or foil packaging. The noninvasive technique has gained attention as the evaluation process can be performed without affecting the ingredient and the original form of the food. Many different noninvasive techniques have been studied and developed for detecting foreign bodies.

The aim of this paper is to describe some of the latest techniques and approaches that are conducted on food products to give a clear viewpoint on applications for detecting the grits that are present. The fundamental principles of the technique including X-ray, U-NET-based, thermal imaging, hyperspectral imaging, and ultrasound, are briefly elaborated. Various research regarding those techniques for detecting grits in several types of foods is also analyzed and discussed [13-14].

II. BASIC METHODOLOGY

The fig.3 shows the basic block diagram of Grit Detection in Sustenance by using DEXA images. Two sample images of the sustenance are taken for processing. First, display and acquire two images at different voltage values. These projections must be aligned and corrected for dark fields and flat fields. Then both images are combined together to a single quotient using thickness correction pre-processing. The main aim of this step is to create an image where the pixels of the main object are close to zero values, and the presence of grit leads to large non-zero intensity. To compute these intensities, we tackle a segmentation method that divides the image into phases and finds the intensity values. Determine bad objects based on the intensity values obtained by the segmentation.

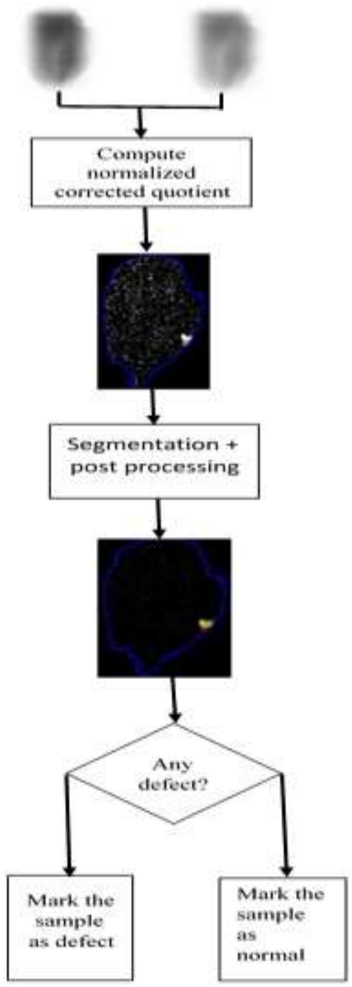

Fig 1. Block diagram of Grit detection

Dual-energy Projection Pre-Processing: X-ray imaging can be used to create projections of the sample under examination. The value of each pixel in such a resulting projection depends on the integral absorption of the material of the object on the corresponding trajectory. Main and foreign objects absorb radiation differently, resulting in pixel intensities. However, the shape of the sample to be inspected is not known in advance. Therefore, the pixel intensity is not constant as the value of the pixels in the object area depends on the thickness of the sample. Two images taken at different voltages provide additional information as material absorption depends on the X-ray photon energy. A dual-energy projection of the defective sample can be segmented as a two-channel image.

Pre-Processing of Experimental Data: A sample of fanned chicken fillet was scanned using a CMOS detector with a CsI(Tl) scintillator (Dexela1512NDT). The X-ray source was a microfocus X-ray tube with 40 and 90 kV voltages. The fillet was wrapped in a plastic bag and placed in a holder. This experimental setup mimics a floor plan similar to typical data on an assembly line. To illustrate the effect of detector noise, the same samples were measured with different exposure times. Scanning the same product with longer exposure times reduces statistical noise and makes it easier to locate foreign objects. Fig.2 shows the Image preprocessing.

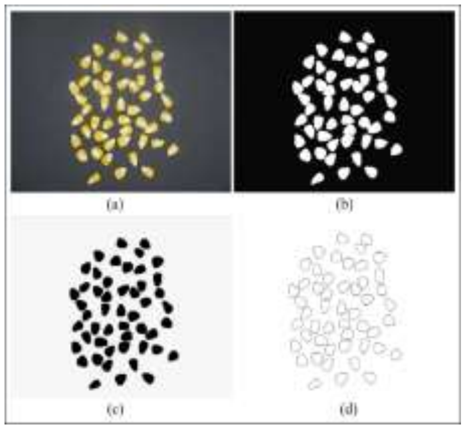

Fig 2. Image preprocessing (a) original color image, (b) morphological processing, (c) inversion, and (d) contour image.

Post-Processing: As an additional option, a post-processing step is introduced to exclude noisy pixels from foreign object regions and make the algorithm more robust. In the proposed methodology, post-processing is the elimination of segmented clusters whose size is smaller than a certain number of pixels. A sample is marked as normal if no clusters are present after preprocessing. Otherwise, the sample is considered to contain defects. For each sample in the experimental data set, we know whether it contains foreign matter. Provides the highest accuracy and improves performance.

Segmentation: The thickness correction preprocessing described in the previous section turns two-channel dual-energy projections into a single image. This work uses an edge-free active contour model to achieve good segmentation quality with high noise. Different penalty weight values lead to different boundary detection, noise sensitivity, and overall algorithm accuracy. Segmentation accuracy can be evaluated if a basic truth (the correct segment of the input) is known for each sample. It mainly focuses on intensity because each object has its own intensity value. Based on magnitude values we can also find odd values. Active contour is a segmentation method that uses energy forces and constraints to separate the pixels of interest from a picture for further processing and analysis. An active contour is defined as an active model for the segmentation process. Contours are the boundaries that define the region of interest in an image. A contour is a collection of points that have been interpolated. The interpolation procedure might be linear, splines, or polynomial, depending on how the curve in the image is described. The primary use of active contours in image processing is to define smooth shapes in images and to construct closed contours for regions. It is mainly used to identify uneven shapes in images.

III. REVIEW OF DIFFERENT PAPERS

A method of detecting foreign objects in packaged foods with irregular texture patterns using a one-class classification method. To protect consumers by ensuring the safety of foods against foreign objects. When the x-ray images of packaged foods contain irregular textures like ramen or spaghetti, the contrast of foreign objects in the image is enhanced by reducing the texture intensity of the food substrate. We employ a one-class classification method to discriminate foreign objects from enhanced images. For real-time processing, the max-min difference of the mask operation is utilized for features of discrimination.

3.1 U-Net-Based Detection:

A Case of Almond and Green Onion Flake Food [15] was taken which includes the detection of foreign objects in the raw materials of food that causes a negative effect on health. To tackle this problem, a method was introduced to detect foreign bodies in raw food materials. He proposed a method for detecting foreign objects without collecting any foreign objects. This method mainly includes two steps. The first step is the training of U-Net to predict the RMF. The next step is the foreign object detection method through raw material in food prediction and background estimation. This method used deep learning as the main algorithm to detect foreign objects. The proposed method provides high accuracy of FODM with little effort and no human annotation.

3.2. Ultrasonic testing:

Sound waves with frequencies higher than the upper audible limit of human hearing are called ultrasound. The limit varies from person to person but is approximately 20,000 Hz. The physical properties of ultrasound are similar to the normally audible sound. This type of scientific concept is used in many different fields such as navigation, medicine, imaging, cleaning, mixing, communication, testing, etc. Even in nature, bats and porpoises use this particular technique for the location of prey and obstacles. In the following section, we shall learn about its applications. Ultrasonic signal's velocity is very sensitive to molecular structure and intermolecular connections, which is suitable for determining the composition, structure, and physical state, and detecting a foreign body and defect in processed and packaged foods. The denser material has a faster velocity of the ultrasonic wave. Ultrasonic energy decreases by increasing the distance from the source of the signal which is a result of signal amplitude. In recent years, researchers are working to expand the application of ultrasonic testing to other fields. In [16] authors discovered a potential for ultrasonic testing to be used in food industries. Their approach was successful in detecting foreign bodies in canned food up to 4mm in size. Immersion ultrasonic inspection system.

3.3 X-Ray using Supervised Learning

Supervised learning [17] is the type of machine learning in which machines are trained using well "labeled" training data, and on basis of that data, machines predict the output. The labeled data means some input data is already tagged with the correct output. In supervised learning, the training data provided to the machines work as the supervisor that teaches the machines to predict the output correctly. It applies the same concept as a student learning under the supervision of the teacher. Supervised learning is a process of providing input data as well as correct output data to the machine learning model. The aim of a supervised learning algorithm is to find a mapping function to map the input variable(x) with the output variable(y). Applications of this method include applying artistic filters, tuning an image for optimal quality, or enhancing the images.

Deep learning [18] is a subset of machine learning, which is essentially a neural network with three or more layers. These neural networks attempt to simulate the behavior of the human brain—albeit far from matching its ability—allowing it to “learn” from large amounts of data. He proposed a real-time anomaly detection method for packaged food X-ray images using a supervised learning network. To acquire defective food product data, which is difficult to obtain, a training dataset was constructed using X-Ray data augmentation. , foreign objects were pasted using composition by reflecting X-ray characteristics. As a result, realistic defective food images could be augmented. With the augmented data, 3,000 training data were built, and test data were collected directly. In addition, patch-based training was applied to reduce the loss in high-resolution images, and the accuracy was further improved through post-processing algorithms. The performance on test data shows that our augmented training dataset is highly similar to real data in the field. Furthermore, our method will perform similarly for other types of food.

3.4 Low-density foreign body detection using X-Ray Imaging

This study [19] presents a novel approach for detecting low-density foreign bodies (FBs) in food products using single-shot grid-based dark-field X-ray imaging (SG-DFXI).To detect low-density FBs in food products using the emerging SG-DFXI method that can effectively obtain information related to the food sample's small-angle scattering using the spatial harmonic imaging technique. This method allows using a conventional X-ray source and a single X-ray grid available at an economical price in the commercial market, and it requires a single exposure. An experiment was conducted with food samples containing low density. A quantitative evaluation was conducted based on the contrast-to-noise ratio and relative contrast gain. The proposed method detected low-density FBs barely visible in absorption images. Additionally, the CNR values measured in dark-field images were approximately 2.8–10.5 times larger than those in the absorption images, indicating that the proposed approach significantly improved the ability to detect low-density FBs in food samples. The RCG characteristic was improved as the system's autocorrelation length increased; the RCG value for = 453 nm was approximately 2.5 times larger than that for = 171 nm.

3.5 Unsupervised Dual-energy absorptiometry

The thickness correction pre-processing is performed on the experimental data and does not rely on prior knowledge about the samples. Firstly, two X-ray images of the studied sample are obtained using two different voltages of the X-ray tube. These projections should be aligned, and darkfield and flatfield corrected. Then both images are combined into a single quotient using thickness correction pre-processing. The goal of this step is to create an image where pixels of the main object has close to zero values, and a foreign object presence leads to a sufficiently large non-zero intensity. Segmentation is performed on this image to divide it into two phases with different mean intensities. This leads to a set of clusters corresponding to the regions of the foreign object inclusion. After finding the clustered pixels small pixels are removed using segmentation. The contour algorithm is used in order to find the grit in food objects. Among many other methods in the contour segmentation, the Chan-Vese method operates well even with noisy data, and a high noise level is inevitable for the conveyor belt product inspection. The detection of bones in chicken fillet are tested and observed.

3.6 Thermal Imaging:

Thermal imaging [20] is a technique to convert the invisible radiation pattern of an object into visible images for feature extraction and analysis. Infrared cameras come in three basic types in Thermal Imaging: short wavelength, mid-wavelength, and long wavelength. Each type has its own place in facility maintenance, depending on use and operation. Infrared thermal imaging was first developed for military purposes but later gained a wide application in various fields such as aerospace, agriculture, civil engineering, medicine, and veterinary. Infrared thermal imaging technology can be applied in all fields where temperature differences could be used to assist in the evaluation, diagnosis, or analysis of a process or product [21]. Principally there are two different ways to distinguish between food material and foreign bodies by means of thermography, i.e., either by differing emissivities or by using the different heat conductivities or capacities of the materials shown in fig.3. If there is a relevant difference in the emissivity coefficient of the materials, as shown for magnesium oxide and human skin at 4m. Using Thermography there are two ways in distinguishing food materials and foreign objects in the food materials. The first method is calculating either the emissivity difference or different heat conductivities or capacities in the food materials. The second method is to apply heat to the materials and observe their penetration into the materials. So that using heat conductivities they can be distinguished. The food materials can also be distinguished using infrared radiation. Giusto approached the analysis like Morphological and statistical analysis. Adaptive Binarization is also played a vital role in producing good contrast images.

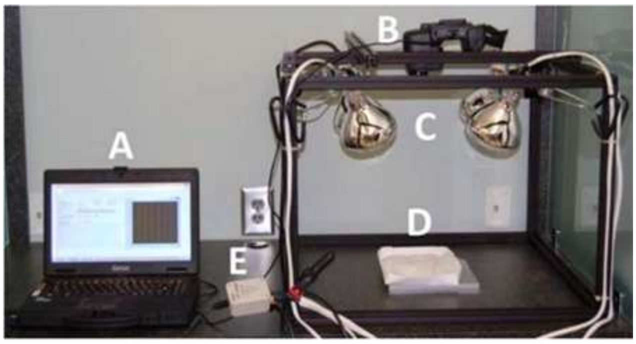

Fig.3 An example of a thermal imaging measurement setup. (A) operating terminal; (B) thermal camera; (C) heat lamps; (D) sample stage; (E) USB power relay for lamp control.

3.7 Hyper spectral Imaging:

In Hyper spectral the term hyper means too many and it refers to a large number of measured wavelength bands. Hyper spectral images are used to provide sufficient spectral information to recognize and differentiate spectrally distinctive materials shown in fig.4. A study [22] was to examine the possibility of using near-infrared hyper spectral imaging for detecting foreign substances that frequently occur in the meat processing industry. The meat used was chicken breasts, and 5 pieces of bone were used as the foreign material that was directly obtained by workers at the industrial site. A reflective spectrum was obtained for nine chicken breast fillets. The acquired spectra are pixel spectra and mean spectra. The measured data are dark reference, white reference, and spectral images of the sample. From the measured spectral data, hyper spectral image data were corrected using the dark

Table 1: Comparison of various proposed techniques

Author	Year	Paper Name	Technique	Result
Hyunwoo Lim, Jonghyeok Lee	2022	Low-density foreign body detection using X-Ray imaging	single-shot grid-based dark-field X-ray imaging (SG-DFXI).	Detected the low-density FBs in food products using this method.
Guk-Jin Son	2021	U-Net-Based Foreign Object Detection Method Using Effective Image Acquisition System.	Deep Learning Foreign Object Detection Method.	This provides high accuracy of FODM with little effort and no human annotation.
Vladyslav Andriiashen, Robert van Liere	2021	Unsupervised foreign object detection based on dual-energy absorptiometry in food industry.	Active contour Segmentation and chan-vese method.	The detection of bones in chicken fillet are observed.
Kangjik Kim, Hyunbin Kim	2020	X-Ray using Supervised Learning	Supervised Deep Learning.	defective food product data from packaged food was found with accuracy of 94%.
Jongguk Lim, Ahyeong Lee	2020	Hyperspectral Imaging	Hyperspectral reflectance imaging subtraction imaging and clustering.	Considering 45 bone fragments, 42 were detected, resulting in a detection accuracy of 93.3%.
Meftah, H. and Mohd Azimin	2015	Ultrasonic testing	Ultrasonic imaging technique.	The results show the viability of an inspection system based on ultrasound energy for foreign body detection in the alimentary industry.
Christian Jördens, Martin Koch	2008	Tetra hertz Imaging	Conventional tetra hertz Imaging and image processing.	Detection of a glass splinter inside a chocolate bar filled with hazelnuts has resulted.
LINE Jae-Sung Kwon, Jong-Min Lee, Whoi-Yul Kim	2008	Real-Time foreign body detection using X-Ray Imaging	One class classification method	A High detection ratio for foreign bodies is obtained.
Giaime Ginesu, Daniele D.Giusto	2004	Thermal Imaging	Adaptive Binarization including Morphological and Statistical imaging	The foreign objects were projected more brightly in the structured background

reference and white reference. Then, the mean and pixel spectra of the samples were extracted from the calibrated hyper spectral image data.

3.8 Terahertz Imaging:

The terahertz wave lies between the microwave and infrared regions of the electromagnetic spectrum at frequencies between 0.3 and 10 THz and the wavelength range from 100 mm to 1 mm [23]. It can operate in transmission mode or in reflection mode and it can be used in the time and space domain. Radiant energy from 1 to 10 meV causes the molecules to oscillate and rotate to give the wavelength properties [24-25]. Terahertz waves have several advantages when used as a non-destructive testing method because they produce low photon energies and are capable of penetrating into different materials [26-27]. In the field of food safety [28] used terahertz pulse imaging systems to detect the presence of foreign bodies in chocolate. The experiment was conducted using a single-pulse structure and a double-pulse structure. The single pulse structure is used to detect hazelnuts because some chocolate products contain this ingredient. The dual pulse structure has been used to detect non-metallic foreign objects such as stone fragments, glass, and plastic. All the nuts are buried inside the chocolate bar. The experiment was performed using a built-in intensity between 0.4 and 0.75 THz, and the presence of foreign bodies was assessed on the basis of the refractive index. The results showed that chocolate and hazelnuts had a refractive index of 1.75, while the plastic pieces had a lower value of 1.5. However, the high refractive index values obtained in the case of glass and rock have values of 2.6 and 1.9, respectively. It is shown in fig.5.

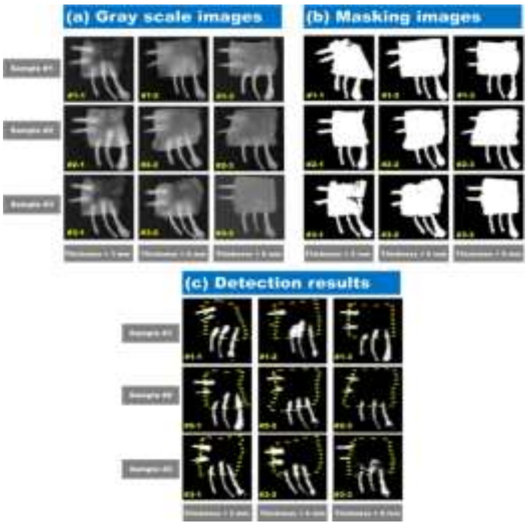

Fig.4 Hyper spectral images of chicken breast fillet samples obtained after applying the subtraction algorithm (HSI1153.8 − HSI1480.2): (a) grayscale images, (b) binarization results based on the threshold intensity, and (c) detection results of bone fragments in chicken breast fillets obtained after applying the subtraction image algorithm.

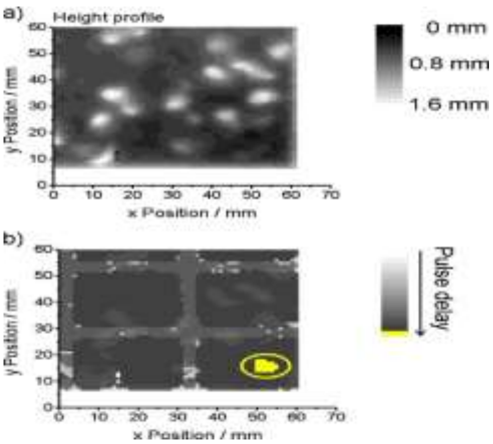

Fig.5. (a) Height profile from the back of the chocolate bar. (b)Thickness-corrected delay image for the pulse maximum.

3.9 Real-Time Detection of Foreign bodies using X-Ray Imaging:

One-Class Classification, or OCC for short, involves fitting a model on the "normal" data and predicting whether new data is normal or an outlier/anomaly. A one-class classifier aims at capturing characteristics of training instances, in order to be able to distinguish between them and potential outliers to appear [29]. Jong-Min Lee presented a novel method for detecting foreign objects in packaged foods. The work has aimed to meet the criteria for a foreign object detection method that obtains a high detection ratio for foreign objects, high reliability, and real-time processing for a manufacturing line. In order to achieve these aims, we modified the zero-mean image by taking its positive response to enhance the contrast of the foreign objects and to reduce the effect of the texture component. The simple texture features acquired by the mask operation are used for classification to reduce time consumption. Through the experiment, in the case of the detection of high-density foreign objects, the proposed method showed high accuracy without a false positive. However, the detection capability is insufficient for foreign objects of a small size or low density such as Teflon and rubber. Therefore, the proposed method requires further research to improve the detection accuracy of foreign objects of low density and small size.

IV. CONCLUSION

This review briefs the applications of various techniques for detecting foreign bodies in food products which included X-ray, thermal imaging, hyper spectral imaging, ultrasonic, and terahertz. It was observed that foreign body detection in many foods can be done using many techniques. Several types of foreign bodies have also been investigated to recognize the performances and limitations of the techniques. In addition, applications of each noninvasive method were also presented. Understanding the best way to evaluate food products is important to the food manufacturer. Techniques such as hyper spectral and thermal imaging are suited to distinguish between food (e.g., fruits, chocolates, and meats) Conversely, X-rays, ultrasound, and terahertz are more appropriate to observe the internal attributes of the food by exploiting the high penetration capabilities of these techniques. Some criteria are essentially being considered; (1) Accuracy produced by the Technique, (2) foreign body categories, and (4) low-cost system which will be the significant trend in its future application in food safety and quality aspect.

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