Food Safety Inspection and Control Using Hyperspectral Imaging

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Abstract

Food safety is an important public concern, and outbreaks of food-borne illnesses can lead to disturbance to the society. Consequently, fast and non-destructive methods are required for sensing the safety situation of produce food. As an emerging technology, hyperspectral imaging has been successfully employed in food safety inspection and control. Additionally, other studies, including detecting meat and meat bone in foodstuffs as well as organic residue on food processing equipment are also reported due to their close relationship with food safety control. Hyperspectral imaging, like other spectral imaging, collects and processes information from across the electromagnetic spectrum. The goal of hyperspectral imaging is to obtain the spectrum for each pixel in the image of a scene, with the purpose of finding different objects, identifying materials, or detecting processes.With these applications, it can be demonstrated that miscellaneous hyperspectral imaging techniques including near-infrared hyperspectral imaging, fluorescence hyperspectral imaging, etc., or their combinations are powerful tools for food safety surveillance.

Keywords: *Hyperspectral imaging technique, Image reconstruction, Spectrum, Defects, Wavelengths.*

1. Introduction

Food safety refers to the proper handling, cooking, and preservation of food in order to protect the people from food-borne illnesses caused by microbes such as bacteria, fungi, parasites, and viruses, Stomach aches, diarrhea, vomiting, fever, muscle aches, and more can be caused by a food-borne illness. So as to detect any defects in the food produced we will be using an emerging technology, which is hyper spectral imaging. Hyperspectral imaging has been successfully employed in food safety inspection and control. Hyperspectral imaging technique acquires both spatial and spectral information from a target by combining traditional imaging and spectroscopy methods, making it a powerful tool for many food and agricultural applications. Hyperspectral images are three-dimensional (3-D) in nature, with two spatial dimensions and one spectral dimension. The 3-D hyperspectral image data can be collected by three major image acquisition methods: point-scan, line-scan, and area-scan methods [1]. It is envisaged that hyperspectral imaging can be considered as an alternative technique for conventional methods in realizing inspection automation, leading to the elimination of the occurrence of food safety problems at the utmost. Since food commodities usually move along processing and production lines, the line scan hyperspectral acquisition method naturally fits to inspect the individual moving food items. Line scan hyperspectral imaging techniques have drawn tremendous interest from both academic and industrial areas, and have been intensively researched and developed for food and agricultural applications during the past 15 years [1,4]. With the introduction of new measurement concepts and instruments, line-scan hyperspectral techniques are continuously evolving to expand the scope of their applications.

2. Literature Review

Yao-ze Feng and Da-wen Sun provides comprehensive information on the recent development of hyperspectral imaging applications in food and food products, quality inspections. Hyperspectral imaging and spectroscopic technology are rapidly gaining tool for food quality and safety assessment is provided. In this paper imaging applications are discussed in relation to various fields such as, in food quality inspection, security issues, chemical gas reactions, detection of rare materials. Furthermore, this platform can be widened by introducing different spectral profiles[1].

Seoung Wug Oh has presented a framework for reconstructing hyperspectral images by using multiple consumer-level digital cameras. Due to the differences in spectral sensitivities of the cameras, different cameras yield different RGB measurements for the same spectral signal. It introduces an algorithm which combines and converts different RGB measurements into a single hyperspectral image for both indoor and outdoor scenes. But it runs into a problem when the system was used under a fluorescent illumination. This is due to the rather peculiar spectrum of fluorescent lights[2].

R. M. Nguyen et. al has focused on a training-based method to reconstruct a scene's spectral reflectance from a single RGB image captured by a camera with known spectral response. It has explored a new strategy to use training images to model the mapping between camera specific RGB values and scene reflectance spectra. In addition, it has also shown an effective approach to recover the spectral illumination from the reconstructed spectral reflectance of an RGB image. Though it lacks in the reconstruction of 3d area or space[3].

Mehl,p et. al has discussed the increasing occurrence of food borne diseases and the difficulty of treating them makes it desirable to ensure as close as possible to zero contamination level. To reach this goal, various techniques have been proposed by researchers and some of them are still under investigation, such as biosensors, optical sensors, and bio films to test the safety and quality of fruits and vegetables. One of the analytical methods applied to hyperspectral imaging is the classical multivariate analysis technique of principal component analysis. Filters at 705 and 460 nm are apparently more essential for the design of the present system than 575 nm. The present multispectral analysis system is actually capable of classifying normal and abnormal apples for the three cultivars. The classification for normal/abnormal apples is found to be close to 63 and 70% for Red and Golden apples, respectively[4].

Kalkan.h et. al has explained that hyperspectral imaging system isused to detect aflatoxin-contaminated hazelnut kernels and red chilli peppers. Classification accuracies of 92.3% and 80% were achieved for aflatoxin-contaminated and uncontaminated hazelnuts and red chilli peppers, respectively. The aflatoxin concentrations were decreased from 608 to 0.84 ppb for tested hazelnuts and from 38.26 to 22.85 ppb for red chili peppers by removal of the nuts/peppers that were classified as aflatoxin-contaminated[5].

2.1. PROBLEM STATEMENT

As a global issue, food safety is receiving increasing attention in both developed and developing countries. However, in spite of its high prevalence and importance, there is no direct scientific definition for food safety available. Food safety is a discipline aiming to ensure that food is safe enough "from-farm-to-fork" for consumers so that outbreaks of food-borne illness can be reduced. The concept of food safety involves physical, chemical, and biological contamination and other associated hazardous poisons. Hyperspectral imaging collects and processes information from across the electromagnetic spectrum just like other spectral imaging. The goal of hyperspectral imaging is to obtain the spectrum for each pixel in the image of a scene, with the purpose of finding objects, identifying materials, or detecting processes. .

Hyperspectral Image Reconstruction:

- HSI framework relies on multiple observations from different cameras. To reconstruct a high -resolution hyperspectral image, a registration process is necessary to find correspondences between images to build the observations. To allow us to focus on the HSI reconstruction, we captured planar scenes so that homographs could be used for the registration. The hyperspectral imaging algorithm itself is general that can be used for non planar scenes with a dense registration method such as dense stereo matching [7], patch match [6], etc.
- The light provided by the light source interacts with the food samples, and the detected portion containing both physical and chemical information of the sample will be dispersed and projected onto a two-dimensional detector array in an imaging spectrograph, which serves the same role as human eyes do.
- The imaging spectrograph normally covers a wide range of both visible and near-infrared region; however, for human eyes, only three bands (red, green, and blue) are differentiated. The acquired signal will then be transferred into a computer for further processing, including digitization, storage, modelling, and decision-making, in a similar way as the brain works. After image reconstruction-processing, modelling results in a spectral image which can be used to identify contaminants by comparing the image wavelength sensitivities to the wavelengths of a verified food item which is safe to consume. If the sensitivities match, then the food item is safe to consume.

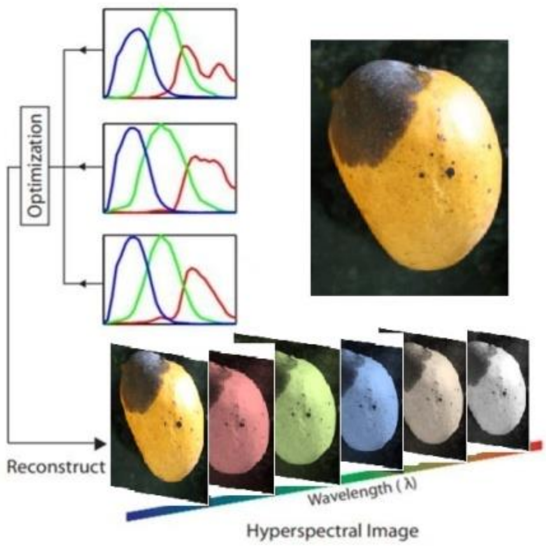

Figure 1 : Hyperspectral image- Reconstructed image obtained after processing of the image.

2.2. SYSTEM DESIGN

Food safety is a great public concern, and outbreaks of food-borne illnesses can lead to disturbance to the society. Consequently, fast and non-destructive methods are required for sensing the safety situation of produce. As an emerging technology, hyperspectral imaging has been successfully employed in food safety inspection and control. Hyperspectral imaging technique acquires both spatial and spectral information from a target by combining traditional imaging and spectroscopy methods, making it a powerful tool for many food and agricultural applications. Hyperspectral images are three-dimensional (3-D) in nature, with two spatial dimensions and one spectral dimension. The 3-D hyperspectral image data can be collected by three major image acquisition methods: point-scan, line-scan, and area-scan methods [1]. It is envisaged that hyperspectral imaging can be considered as an alternative technique for conventional methods in realizing inspection automation, leading to the elimination of the occurrence of food safety problems at the utmost. Since food commodities usually move along processing and production lines, the line-scan hyperspectral acquisition method naturally fits to inspect the individual moving food items. Line scan hyperspectral imaging techniques have drawn tremendous interest from both academic and industrial areas, and have been intensively researched and developed for food and agricultural applications during the past 15 years [1,4]. With the introduction of new measurement concepts and instruments, line-scan hyperspectral techniques are continuously evolving to expand the scope of their applications.

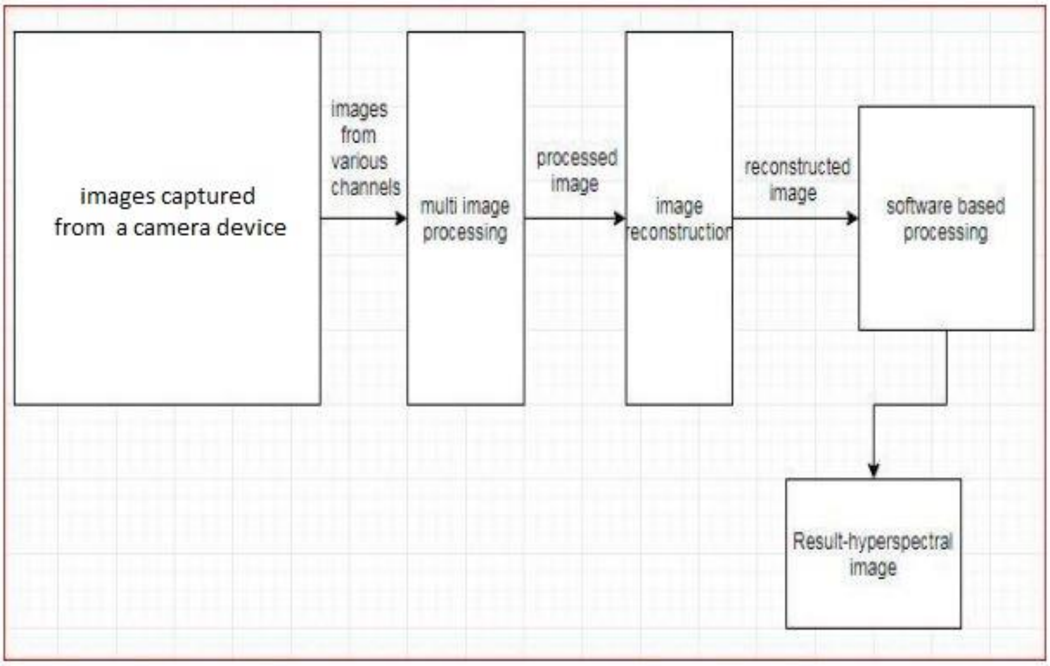

Figure 2: Block Diagram of Proposed System.

3. IMPLEMENTATION

Java programming language has been used to implement this model. The IDLEs Netbeans as well as eclipse have been used for this purpose. We have also used wavelength datasets for acquiring the different wavelength values of different types of food products available along with the food datasets.

$$Hue = (650 - wavelength)*240/(650-475) \quad [12]. \qquad (1)$$

The above equation is used for finding out wavelength from hue value. .

4. RESULTS

After conducting various experiments we have obtained the following results regarding food samples

Figure 3 : Sample-1 is a captured image of an apple

Figure 4 :RGB image of the sample.

We can see the image of the above sample after ripeness, spots and dents.

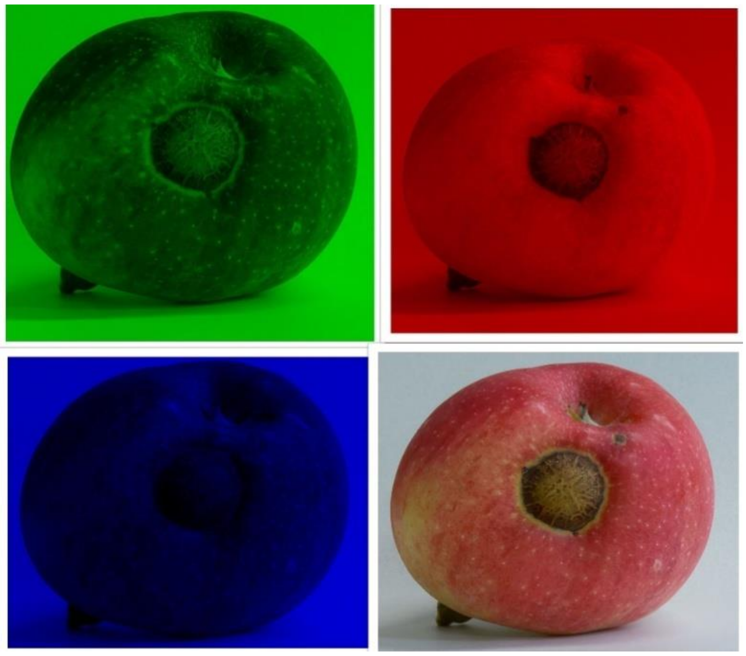

Figure 5: Intermediate stages of image reconstruction.

We can see the final difference between the two images of the same sample after the image reconstructing process[3].

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Fig 4 shows the spots where the defects occure within the sample.

Fig 5 shows the process of reconstruction

Figure 6: Fresh and rotten food products

Fig 6 shows the fresh and rotten food products which are used in our experiment.

Following table contains the results after processing the images of food products and obtaining the final wavelength.

SR. NO.	Product	RGB Value	Hue	Wave-length(mm)
1	Fresh Apple	203,46,39	2.56	648
2	Fresh Apple	206,47,41	2.56	648
3	Fresh Apple	224,91,71	2.7	647.86
4	Fresh Apple	196,47,41	2.88	649.23
5	Fresh Apple	200,66,55	2.71	647.05
6	Rotten Apple	196,97,14	27.36	630
7	Rotten Apple	252,161,88	26.71	630.52
8	Rotten Apple	202,128,29	34.33	624.98
9	Rotten Apple	137,72,32	22.85	633.33
10	Rotten Apple	249,212,185	25.31	631.54
11	Fresh Guava	180,197,93	69.83	599.08
12	Fresh Guava	174,190,91	69.16	599.57
13	Fresh Guava	170,188,86	70.59	598.52
14	Fresh Guava	189,203,118	69.88	599.05
15	Fresh Guava	164,181,77	69.81	599.1
16	Rotten Guava	97,92,86	32.72	626.141
17	Rotten Guava	74,62,12	43.39	618
18	Rotten Guava	109,96,54	45.82	616.95
19	Rotten Guava	189,203,128	71.2	598.08
20	Rotten Guava	81,80,24	58.95	607.02

Table 1 : Wavelength Values of fresh and rotten food products.

In this experiment we have worked on two food products apples and guavas. As we can see in the table that fresh apple has an average wavelength of 648mm and rotten apple has an average wavelength of 629 mm. Similarly, fresh guava has an average wavelength of 599 mm and rotten guava has an average wavelength of 618 mm. In the case of apples the wavelength of fresh apples compared to rotten apples is decreasing by ~ 20 mm and in the case of guavas the wavelength of fresh guava compared to rotten guava is increasing by ~19mm.

5. CONCLUSION

This paper summarizes the application of hyperspectral imaging in food safety inspection and control. Hyperspectral imaging integrates two popular technologies, that is, spectroscopy and computer vision, to present both spectral and image information of food products at the same time. The main advantage is accuracy and wide range of detection module under one roof. The primary advantage to hyperspectral imaging is that, because an entire spectrum is acquired at each point, the operator needs no prior knowledge of the sample and post processing allows all available information from the dataset to be mined. The primary disadvantages are cost and complexity. Fast computers, sensitive detectors, and large data storage capacities are needed for analyzing hyperspectral data obtained after implementing. Significant data storage capacity is necessary since hyperspectral cubes are large, multi-dimensional datasets, potentially exceeding hundreds of megabytes.In our sample experiment we found out that all the fresh apples had a range of 640 to 650 mm wavelength whereas, the wavelength of rotten apples ranges between 624 to 633mm. Similarly, using this method we have also able to find defects in different food products. .

6. USAGE AND FUTURE SCOPE

We have shown that with the help of hyperspectral imaging we can differentiate between a rotten food item and undamaged food item by comparing their spectral sensitivities. This process can also be implemented for finding defects in any type of new food products. This experiment was conducted using a common light source and can be extended to work with different light sources.

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