Conference Paper

Experiment on Laser Speckle Imaging of Apples Using A CMOS Camera

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Abstract

Laser Speckle Imaging recently has become a promising tool to assess fruit quality and can be applied in fruit sorting. It is a non-destructive, optical method which uses light scattered of fruit surface after illuminated by laser light. Laser speckle imaging methods use He-Ne laser or diode laser as the light source yet both lasers have differences in performance and price. Diode lasers are more preferable due to their efficiency, low cost, small and compact, and varied wavelength. In this research, an optical system which consisted of a laser source and a CMOS camera was used for Laser Speckle Imaging. A 632,8 nm He-Ne laser and a 650 nm diode laser were used, their performances were compared. The samples were two kinds of apples, *Red Delicious* and *Fuji,* five samples for each cultivar. The laser light was expanded using a beam expander hence illuminated on the apple surface at 30^o angle. A monochrome Thorlabs CMOS camera with camera lens was used to record the speckle patterns of the apple surface. Both lasers were kept at the same laser power by Neutral Density Filters. ImageJ software was used to calculate the gray value of the speckle pattern for each sample, the speckle gray values were compared for different laser light sources and apple types. The results showed that there is a significant difference in gray value level between both apples. Higher maximum gray values were found on the *Fuji* apples compared to the Red Delicious apples which were about 21.7 % when using He-Ne laser and 18.3 % when using diode laser. Higher maximum gray value for Fuji apples could be due to their rounder shape, firmer skin and flesh, they scatter more light. The curvature and the firmness of the fruits affected the gray value level. For each apple type, there was a slight difference in maximum gray values for both laser sources. Higher gray values were obtained when using diode laser compared to the He-Ne laser, 22.0 % difference for Fuji apples and 25.2 % difference for Red Delicious apples. These could be because of the less coherence, wider bandwidth, and irregular beam shape of the diode laser that it scatters more light and suppresses speckles.

Keywords: Laser Speckle Imaging, laser types, ImageJ, CMOS camera, apples

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1. Introduction

Fruits dan vegetables are valuable agricultural commodities, however some problems still exist such as plant diseases and post harvest sorting problems of fruits and vegetables. Plant diseases of fruit and vegetables caused by pathogens can create major economic loss in agriculture industries. Sorting fruits and vegetables before and after harvest is a very important task, the fastest and reliable sorting system which can asses maturity level is needed to maintain the quality of fruits and vegetables. Some fruits are mature after harvest but need to ripe, knowledge on the ripeness level is also needed for packaging and storage time purposes. Sankaran *et al.*(2010) has reviewed varied techniques that have been developed to detect plant diseases and the urgencies to develop a real time, fast, economical, and reliable system that is able to detect the health of plants [1]. Abbott has also reviewed some possible techniques to evaluate the quality of fruits and vegetables. Optical methods which use light with different wavelengths are the potential tool to measure and evaluate the fruits and vegetable defects. Fruit and vegetables tissues have optical properties hence can be used to assess their quality. Visible and NIR lights are being developed and able to detect fruits and vegetables contents such as proteins, carbohydrates, and fats [2]. More advanced researches on preharvest and postharvest sorting problems of fruits and vegetables are needed in order to sustain agriculture industries.

Laser is a light source that has been known to have many applications. The properties of laser light that differentiate it from other light sources makes applications of laser increase rapidly. The applications of laser have been found widely in agricultures. One of the reasons is the nondestructive effect of laser light to the biological tissues or samples compared to the molecular methods which are often destructive, more expensive, and time consuming. There are some optical methods that have been developed and got much attentions recently in agricultural research such as LICF (*Laser Induced Chlorophyll Fluorescence*) spectroscopy on plant diseases, Hyperspectral spectroscopy imaging and LSI (*Laser Speckle Imaging*) for fruits and vegetables. Some of the methods apply lasers as the light sources. Laser types used mostly He-Ne laser and diode laser. Some experiments such as Hyperspectral imaging use Halogen lamps or Leds as the light sources. There some advantages using laser than lamps such as monochromacities, coherences, higher power, more eficient in energy comsumption, and low cost. He-Ne lasers and diode lasers are often used in LCIF and LSI experiments because they are low cost, compact, eficient compared to other types of lasers. However, compared to He-Ne lasers, diode lasers have some drawbacks such as less beam quality, less coherence, and sensitive to environmental conditions [3].

Optical Instruments that can be used in fruits and vegetables sorting which are accurate, low cost, portable, needs to be developed. Many researches have been done in developing the instruments especially the sensor used. The sensors used are photodetectors which can be a photo diode, CCD arrays or CMOS camera, the latter is known as the imaging detector. CCD cameras and CMOS camera have been used in computer vision techniques for sorting and grading fruits [4,5]. The CMOS cameras are preferable because they are eficient in cost and energy. CCD and CMOS camera are used for imaging technique which images of the object being investigated can be recorded and processed.

Laser Speckle Imaging (LSI) is a system which uses the speckle patterns to investigate the properties of the surface of an object. LSI has been developed for many purposes in assessing fruits quality and ripeness, the quality of orange fruits [6], the attribute quality of apples [7], and the ripeness of tomato [8]. Laser speckles are obtained when a diffuse surface illuminated by laser light. The speckle pattern consists of granular black and white spot. This is an interference pattern due to interference of lights reflected or scattered from different part of the surface being illuminated. The destructive interference creates dark speckle while constructive interference results in bright speckle. The laser speckle is a random phenomenon hence needs to be described statistically. Gray value and contrast are parameters which are usually used to describe a property of a speckle pattern. They are can be calculated using an image processing software such ImageJ. Contrast is simply represented by the ratio of the standard deviations and the average intensity [9].

2. Material and Methods

An optical system consisted of laser sources, a sample plate, a beam expander, a USB CMOS camera has been used for an experiment in Laser Speckle Imaging. The system was applied to asses the differences in speckle profile between two kinds of apples and two kinds of lasers. The samples were Red Delicious and Fuji apples. Each cultivar consisted of 5 samples for each laser with approximately the same equitorial diameter, color, shape, and weight. The laser sources used were a 633 nm He-Ne laser and a 650 nm diode laser. Both lasers were kept at the same power using neutral density filters. The dynamics of the speckle patterns will not be addressed in this paper . The camera was also equipped wih software for recording and saving the speckle pattern images. The images were latter processed using ImageJ software. The speckle profiles were represented by the gray value levels obtained by ImageJ software.

Figure 1 showed the optical setup for laser speckle imaging experiment. Measurements were performed first using the He-Ne laser, for both cultivars, and then using the diode laser. M1, M2, and M3 mirror were used to send the laser light to the sample surface at 30^o angle. Some neutral density filters were applied to obtain the same laser power at the apple surface. A 50 mm convex lens was used to expand the light beam. The distance of the lens from the apple surface were adjusted to obtain the same size of beams on the apple surface which were less than the apple diameter. The speckle pattern formed on the surface of the apples were recorded by the CMOS camera. The recorded image then were processed using ImageJ software to obtain histograms of gray value for each speckle pattern.

3. Results and Discussion

Results of this experiment were images of speckle patterns recorded by the CMOS camera. The data were analyzed using ImageJ software and presented by gray value histogram and also using graphs of average maximum gray values. The maximum gray value is related to the contrast of the speckle pattern. Variations of data were based of apple types, laser types, and incident angle variation. There were 5 apples for each type so 10 apples for each laser, and three angle variations i.e. 30^o, 45^o, 60^o. The three mirrors were used for easy alignment of beam size and angle. The neutral density

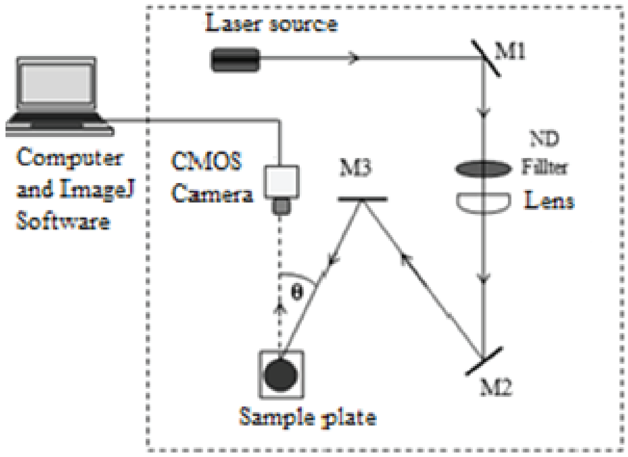

Figure 1: The optical System for Laser Speckle Imaging.

filters were used to reduce the laser intensity reaching the apple surface, the laser power of He-Ne laser was 1,10 mW and of diode laser was 1,11 mW. The sizes of laser beam for both lasers at the surface were made closely equal. The gray value were taken for the whole image without background substraction.

Figure 2 showed the comparison of the average gray value level of speckle patterns for Fuji apples at 30^o angle when different laser source was used. The distributions of the speckle pattern were closely identical because of careful laser beam setup on the apple surface. However, the maximum gray value of speckle pattern when using the diode laser was higher by 22.0 %. Figure 3 showed the average gray value level of speckle pattern for Red Delicious apples taken also at 30^o incident angle. The maximum gray values for both laser were different by 25.2 % and the distribution peak was shifted further to the right compared to the those of Fuji apples. Different results for different laser could be caused by different characteristics for both lasers. He Ne lasers have better beam quality, longer coherence length, more stable power and pointing. The He Ne laser has a slighltly smaller wavelength and unpolarized. Two factors that can suppress speckles are illumination of an object by sufficiently incoherent source and by wider spectral bandwidth [10], these could be the reasons why some imaging systems use a diffuse white light for illuminating objects, to reduce speckles. The diode laser resulted in higher gray value could be dominantly due to its irregularity in beam shape which scatter more light, its less coherence, and its wider bandwidth.

The maximum gray value of both apple types was different when using the same laser type. The He-Ne laser gave higher gray value for Fuji apples by 21.7 % difference compared to the Red Delicious apples while the diode laser had 18.3 % difference. The differences in gray value level for both apples could be due to the apple characteristics. The color of Fuji apples are between striped yellow to red while the color of Red delicious apples are from striped red to dark red. The shape of Fuji apples are more round while the Red Delicious apples are conic shape. The Fuji apples have dense flesh while the Red Delicious tissue is less dense or firm [11]. Those could be the reasons why the Fuji apples have higher gray values, more light is scattered.

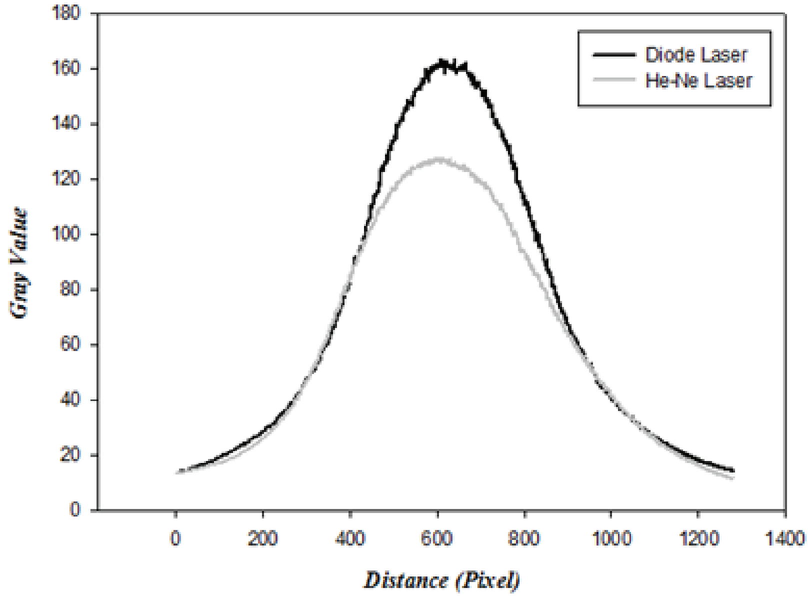

Figure 2: Gray value level comparison between two laser sources at 30^o angle for Fuji Apples.

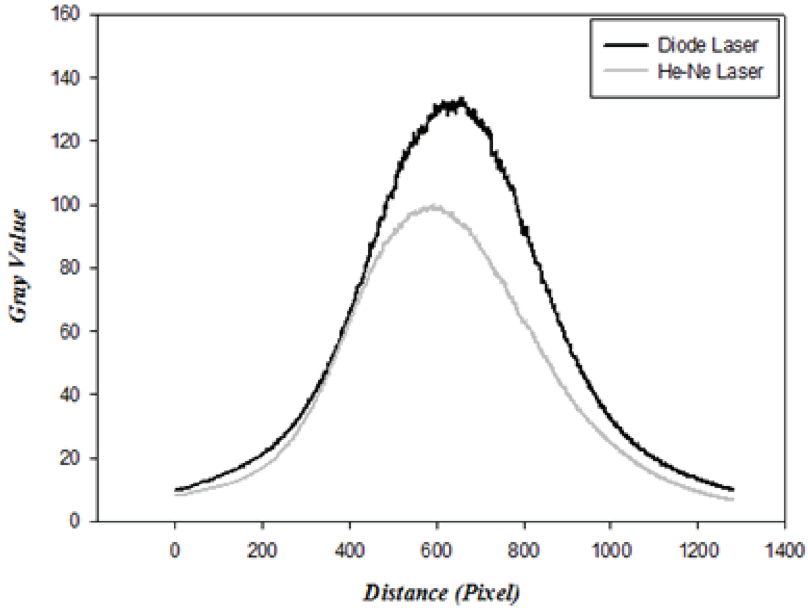

Figure 3: Gray value level comparison between two laser sources at 30^o angle for Red Delicious Apples.

The experiment also explored the effect of incident angle variations on the speckle patterns for both apples and for both laser types. Figure 4 showed the maximum gray value versus angle of incidence for both lasers and apple types. LHF stands for He-Ne Laser and Fuji apples, LHW for He-Ne Laser and Washington apples, LDF for diode laser and Fuji apples, and LDW for diode Laser and Washington apples.

The incident angle affected the speckle pattern for both laser and apple type. The 30^o angle resulted in higher maximum gray value, followed by the 45^o angle, then 60^o angle. The higher was the angle, the smaller was the maximum gray values. The reason could be less scattered light reached the fixed detector when the angle of incidence

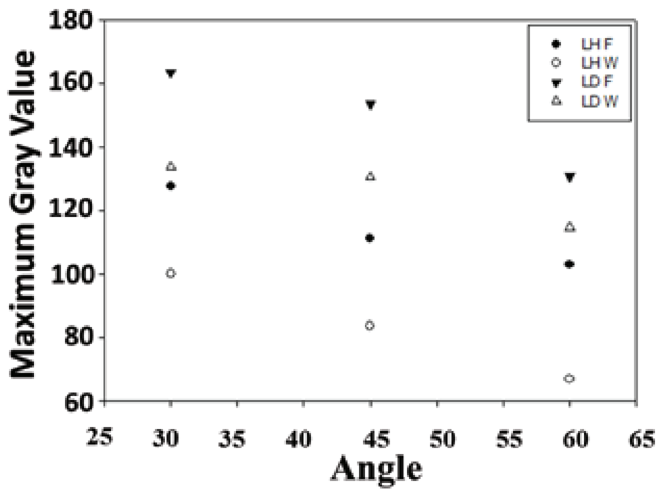

Figure 4: Gray values dependence of incident angles.

was bigger. Figure 4 also showed the differences between the maximum gray value for both laser and apple type for each angle.

4. Summary

This experiment was a simply experiment to answer whether the performance of a diode laser is comparable to the He-Ne laser's in a laser speckle imaging for fruits. The experiment results showed that there is a significant difference in gray value level between both apples. Maximum gray values were higher for *Fuji* apples compared to Red Delicious apples. These could be due to the Fuji apple shape or curvature and firmness. For each apple type, there was a slight difference in gray values for both lasers. The diode laser gave higher gray value than the He-Ne laser. These could be due to less coherence, wider bandwidth, and irregular beam shape of the diode laser.

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