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A new combined optical system for an automatic diagnostics of material surfaces for food technologies

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Abstract
A combined method of diagnosing the surface of biological objects using multispectral imaging technology in polarized light for automatic evaluation of grain quality has been analyzed. The use of polarized light increases image quality for the detection of damaged areas of grain. The intensity of the reflected light from the surface of the grain characterizes the degree and locations on the surface in the damage process. We were analyzing the intensity distributions for different areas of the surface and we proposed a new parameter for quantitative characterization of damages of the samples. This data can be useful for automatic identification of food quality.

1. Introduction

Machine vision technologies [1,2] allow to solve today many problems of automation: identification and recognition, the non-destructive testing, measuring of geometric parameters and temperature of objects, counting the number of products. Technologies of multispectral images in the visible and near infrared regions have been effectively used in the diagnosis and monitoring of surfaces and are at present time the advanced technology for morphological studies [3-6]. A polarized light is also used for the same purpose, but more suitable for biological and medical objects [7-9]. Previously, we proposed a combination of these two technologies for medical research [10]. The combined method of polarized light and multispectral images for studies of surface properties opens a wide range of research and, especially, for applications in the problems of an automatic identification of biological objects and evaluation of a food quality.

The human eye cannot detect the spectral features of the object. An ordinary photocamera works in the visible range of lights too and has the similar properties. Spectral images could be characterizing the physicochemical properties of objects, if its color characteristics match with a spectral bandwidth of a filter. Filters with a very narrow bandwidth (10 nm) were developed and produced by the Japanese company Asahi Spectra Co.Ltd. [11]. A using of these filters opens up new perspectives for experimental studies of multispectral technologies. The importance of an automatic digital image processing has recently increased with the development of multispectral diagnostic method in medicine and biology.

The machine vision technology is developing intensively due to the National Instruments (NI) Company (USA). The NI Company is a leader in this field of science and technology. A NI Vision system has a specialized hardware and software for the computer vision [12], which consists of a collection of technologies (capture) images IMAQ (IMage AcQuision) and software to process and analyze based on LabView^{TM}. The IMAQ hardware includes modules for the images capture from almost all video sources (digital photocameras of different standards and configurations). These modules are designed so that most of the functions can be controlled in software, which greatly simplifies the input image from video converters. By using the IMAQ hardware we can work with images of any spectral range (from X-ray to infrared), different speeds (from single to tens of thousands of frames per second), with a different depth of digitizing (from 8 to 32 bits). The IMAQ interfaces also offer the software of synchronizing for video data with control systems.

2. Experimental Methods and Materials

An experimental setup for multispectral studies in polarized light is shown in Figure 1. We used a digital photocamera Redlake MegaPlus II model EC4020 with a resolution 2048×2048 pixels, a source of polarized light and the different special filters from the Asahi Spectra Company Ltd. The digital camera was connected to a personal computer via an IEEE-1394 interface as shown in Figure 1. The digital camera Redlake MegaPlus II model EC4020 can provide sensitivity to infrared, visible and ultraviolet radiation of light spectrum. The IMAQ module has four inputs for cameras, Ethernet, high-speed IEEE 1394 interface, DVI output, and contacts for the remote control.

The light source was realized with a special halogen lamp. A polarizer installed after the light source (Figure 1). An analyzer was installed in front of the camera. The spectral optical Asahi Spectra filter is been placed between the analyzer and the Redlake MegaPlus II camera. We investigated spectral range from 400 to 900 nm at intervals of 10 nm by using the Asahi Spectra filters. A transmission coefficient of the each filter is in the range of 45 to 60% and is decreasing when approaching to 400 nm (fig.2). The depth of focus of our optical system was sufficient. A measuring of the light intensity of the reflected light from the surface of samples was performed by an optical power meter NewPort 1830C. The optical measuring sensor of NewPort 1830C was located on a level the light source (Fig. 1).

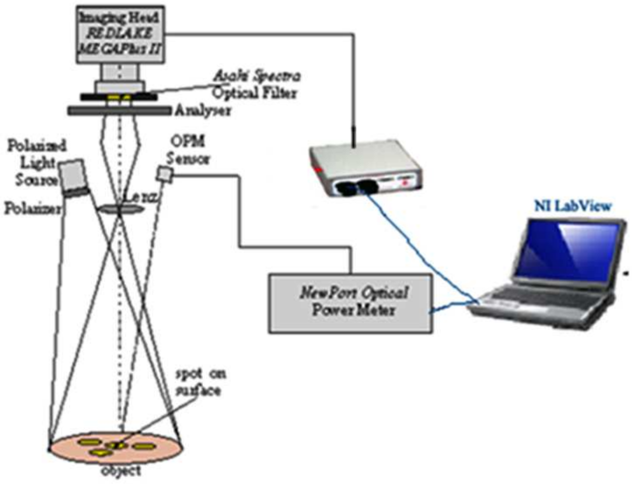


Fig. 1. *An experimental setup for multispectral studies of surface in polarized light.*

Sensors of camera have a photosensitivity in a wide range of wavelengths from infrared to ultraviolet. A figure 2 shows a quantum efficiency Redlake MegaPlus II cameras model EC4020. A calibrations module of the optical system contains relevant data of discrete wavelengths for the light source intensity. Computer processing can adjust and equalize the light intensity for any wavelength. An accuracy of the calibration of the optical system ranges from 2% to 7% depending on the wavelength. The light intensity in the visible and infrared regions of the spectrum was normalized by using the LabView^{TM} program. The computer system also provides an alignment of camera sensitivity across the spectrum through a system of automatic amplification. We used the software of NI Vision with a program LabView^{TM}. The IMAQ module is contacted with computer via the standard interfaces.

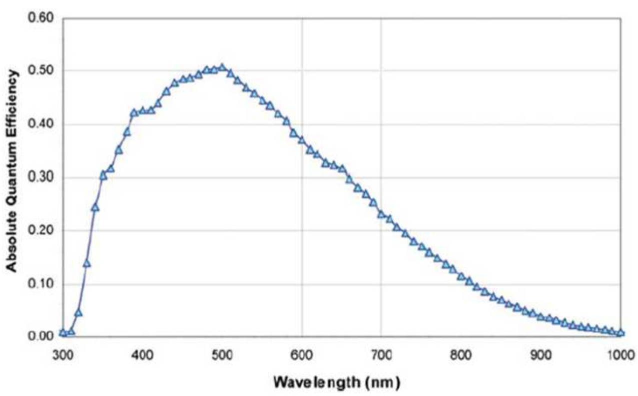


Fig. 2. *An quantum efficiency of the Redlake MegaPlus II camera of model EC4020.*

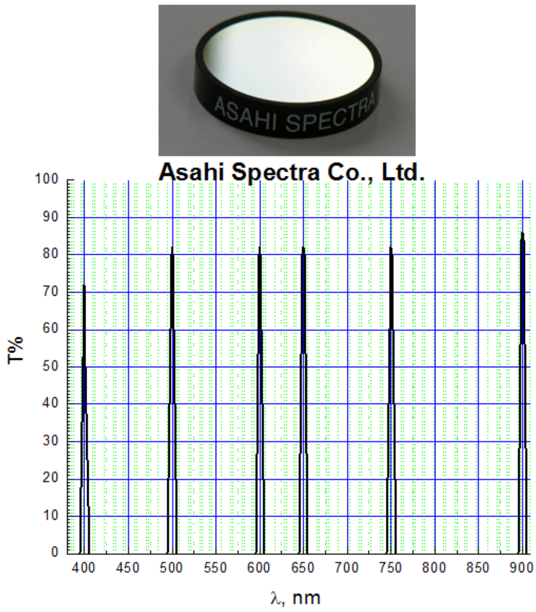


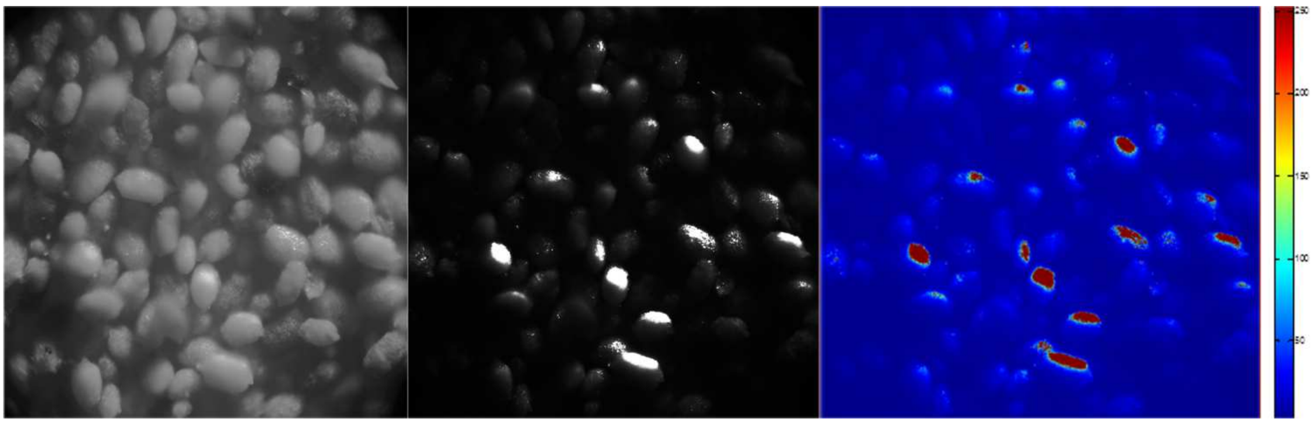
Fig. 3. The special narrow bandpass filters in visible light area from 400 to 900 nm (Asahi Spectra Co.Ltd, Japan [11]).

The multispectral images technologies are a fundamentally new direction of the machine vision for a possible quality identification of industrial products with specific emission spectra. The base of this direction was been created owing to a progress for narrow bandpass filters, designed by Japanese Company (Figure 3). A management program automatically changes filters using a special drum, which was developed by National Instrument in the software LabView^{TM}.

For multispectral studies in polarized light we chose a variety of grains, on the surface of which were not contained and were contained biological changes due to illness. The samples were located on a special table at the bottom of the system (Figure 1).

3. Results and Discussion

Figure 4 shows the photos with a image of grains by using of an ordinary camera (a), after the transforming under spectral images technology in polarized light with a maximal level of polarize (b) and after transformation with the help of NI Vision (c). The photo on the left corresponds to the case as the human eye perceives the image of grains. We practically cannot see that damaged grains have morphological spectral changes (Figure 4, a)). However, a damaged surface of grains we can clearly see in the right picture after spectral images technology in polarized light. The surfaces of grains with damages show a big intensity of the reflected light (Figure 4, b)). The magnitudes of the reflected light beam characterize degree of surface damages. The maximum degree of damages has a maximum intensity of the reflected light. Thus, the machine vision can be used effective to detect the level of changes of surface properties of biological objects (in our case, the damages in a storage process).



a) b) c)

Fig. 4. The image of grains by using of ordinary camera (a), after a transformation under the spectral images technology in polarized light with a maximal level of polarize (b) and after transformation with NI Vision (c).

The black-and-white image (obtained by the Redlake MegaPlus II camera) provides information on the intensity of the reflected polarized light in a very narrow spectral band (through filters of Asahi Spectra Co.Ltd) (see fig.4, b). The maximum intensities of the reflected beam correspond to the damaged surface of the grains. We can identify the damaged grains more clearly by using of this optical effect (see Figure 4, a) and b)). However, the grade of damage for grains may be different (Fig. 4, b). Figure 4,c shows the color gradation of the intensity of the reflected light, which made the LabView^{TM} program automatically. The damaged areas have red color and can be identified maximal clearly.

An intensity distribution of a spot on the image (fig.4.b) as 3D plot is shown in Figure 5. Different spots have different magnitudes of reflected light maximal intensity and spatial distributions. The intensity of the reflected light from the surface of the grain characterizes the degree and locations on the surface in the damage process. The process of such transformations is interesting for researches by their quantitative description. In this case, we can characterize the object of research in the process of degradation of the properties.

We were analyzing the intensity distributions for different areas of the surface. Figure 6,a-d shows the intensity distributions. Figure 6,d corresponds to not damaged surface. This data may be used for a calibration.

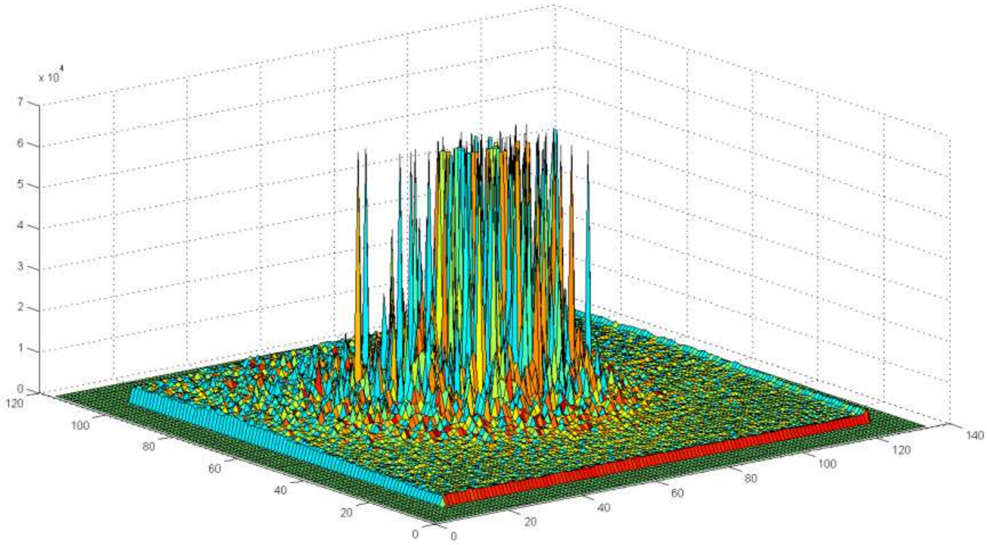


Fig. 5. *3D plot for the spot on the surface image.*

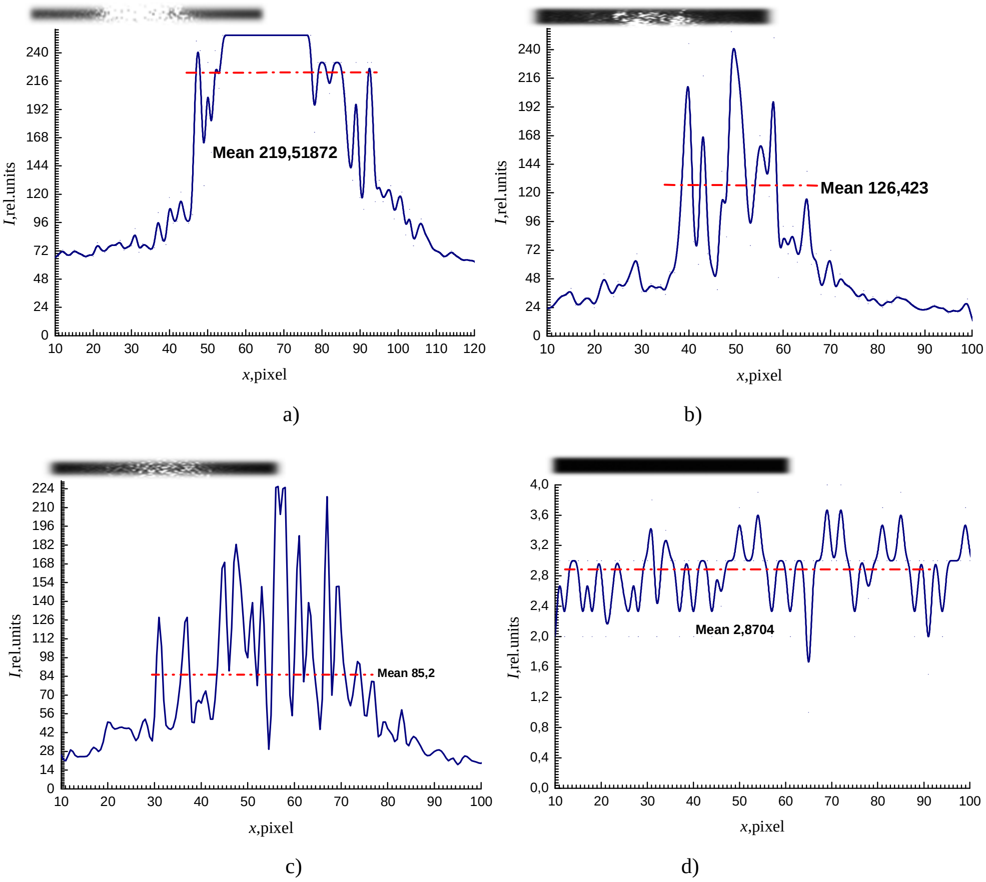


Fig.6. *The intensity distribution for different areas (a,b,c- reflections from the different damaged surfaces, d- the reflection from the not damaged surface).*

The degree of the damage for grains can be estimated as a ratio of the mean intensity I_{mean} of the reflected light in the damage area (fig.5, a,b,c,) to the mean value of reflected light intensity in the samples without damage I_{mean0} (fig.5,d):

$$\alpha = \frac{I_{\mathrm{mean}}}{I_{\mathrm{mean0}}} \qquad (1)$$

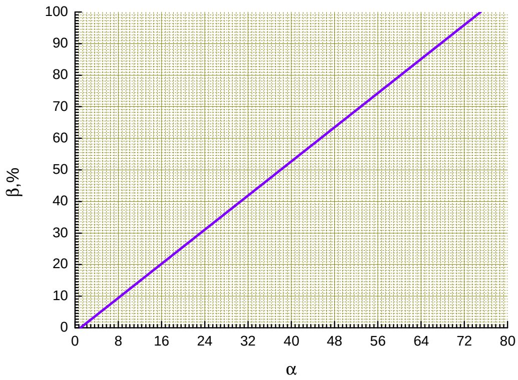


Fig. 7. *A calibration curve β(α).*

We can use the magnitude I_{mean0} as a reference magnitude for the samples without damage. In this case parameter α is equal to 1. The damage degree β corresponds to zero percent. For our experiment the maximal magnitude of parameter α equals 76.477. We consider that the damage degree β corresponds to 100% percent (maximal damages for grains). Figure 7 shows a calibration curve β(α).

4. Conclusions

The machine vision system from National Instrument has modern hardware and software for automatic control of different materials surface and has a good future. The proposed a combined diagnostics method for the surface of biological objects using multispectral images and polarized light technology allows more clearly detecting the spectral changes of materials, first of all, for the biological samples. Measuring of damages of grains can be organized without contact with materials and in their stream. The proposed the parameter β can be useful for quantitative characterization of the food samples. A receiving of streaming data about the damages of grains (β(α)) can be fully automated on the base of the platform of NI vision.

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