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Designing Multispectral Camera Model using VIS-NIR for non-intrusive food quality assessment

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Abstract

One advantage of light-based technology is that it offers non-intrusive analysis. By comprehending how light interacts with food's tissue and examining how it is absorbed and reflected. Multispectral Camera Model (MCM) can rapidly evaluate the food quality without physically destroying it. In this work, the capturing system model that is used to evaluate the quality of food is discussed. The Raspberry Pi 4 serves as the primary controller for the MCM, controlling the LEDs and camera. The MCM contains LEDs with four color modes with spectroscopy carried out in the VIS-NIR bands which are Red (620 – 625nm), Green (522 – 525nm), Blue (465 – 467nm) and Near-IR (peak wavelength in 940nm). One at a time, specific wavelength LEDs are individually illuminated, and for each flash, a sample is simultaneously taken with a Raspberry Camera. The result is that every image captured will be represented as a 3-dimensional data cube containing details of both spectral and spatial space.

1 Introduction

The industry for food is driven by customers. Health consciousness has increased, and individuals are increasingly demanding of high-quality products. In many years, sensory assessment, chemical analysis, and microbiological analysis are the standard techniques to evaluate food quality. However, these techniques often required invasive assessment and the cost of the analysis per unit of measurement could be very significant. New economical, quick, and environmentally friendly strategies have been developed to overcome the drawbacks and limitations of the earlier approaches. Optical technologies are a more recent strategy in a technical sense. [1]

Method	**Subjective/Objective**	**Sample/All**
Sensory	Subjective	All
Chemical	Objective	Sample
Microbiological	Objective	Sample
Optical	Objective	All

Table 1: Comparison of quality assessment technique **[1]**

Table 1 shows each evaluation approach. With the sensory technique being used to evaluate products by sensation through the senses of sight, smell, touch, taste, and hearing. The drawback of this method is that it depends on quality checker, which involves a lot of subjectivity. On contrary, chemical and microbiological method can eliminate subjectivity out of evaluation chain. Nonetheless, these two methods above only perform with one sample at a time and its necessity of invasive examination. Ultimately, the optical method, which interacts with the product via light, can address the limitations of the earlier technology. Biological, physical, and chemical characteristics can be detected through optical methods. *Table 2* compares six key properties of four optical methods.

Features	**Spatial Information**	**Spectral Information**	**3D data**	**Quality-attribute distribution**	**Discrete spectral bands**	**Real-time applica tion**
Imaging	x					x
Spectroscopy		x				x
Hyperspectra l	x	x	x	x		
Multispectral	x	x	x	x	x	x

Table 2: Comparison of the main characteristics of imaging, spectroscopy, hyperspectral imaging, and multispectral imaging techniques. **[2]**

Normal imaging is only capable of providing two-dimensional information and clearly identifying irregular regions on the product. With the use of spectroscopy, the approach can provide significant information regarding how wavelengths interact with the subject but cannot provide imagery, which can be problematic when analyzing. To compensate for this shortcoming, hyperspectral imaging and multispectral imaging are a combination of normal imaging and spectroscopic techniques. Although it provides a wealth of information, capturing a hyperspectral image takes a large amount of time, reducing the availability for real-time applications. Multispectral imaging, which is the reduced form of hyperspectral, is quicker, more affordable, and simpler to use than the original form. In comparison to the hyperspectral approach, scientists are free to select a suitable wavelength rather than the entire spectral band.

2 Material and Methods

2.1 Multispectral Imaging

Hyperspectral and multispectral imaging (HSI and MSI, respectively) are well-known imaging techniques that have their origin in remote sensing. Nevertheless, many other fields of science and industry have benefited from the adaptability of having a camera with a spectrometer integrated into each pixel. Multispectral images are those that capture individual images at specific wavelengths, frequently taken by specific filters or LEDs, across the electromagnetic spectrum (normally the visible (VIS) and near-infrared (NIR) regions) [3]. Multispectral images can be considered as a special case of hyperspectral images in which the wavelength range collected cannot be considered as continuous. That is, instead of a continuous measurement between a certain wavelength range, the multispectral images contain information in discrete and specific wavelengths. Hyperspectral and multispectral imaging provides image information in the spatial domain (x, y) as well as in the spectral domain (λ).

Figure 1 Figure 1 shows a cookie captured with a hyperspectral camera. Water was intentionally added into three areas. These regions are indistinguishable to the naked eye in the visible spectrum. But one of the main elements that can be found under NIR illumination is water. The 1475nm false color image highlighted three areas of the cookie that demonstrate the difference property.

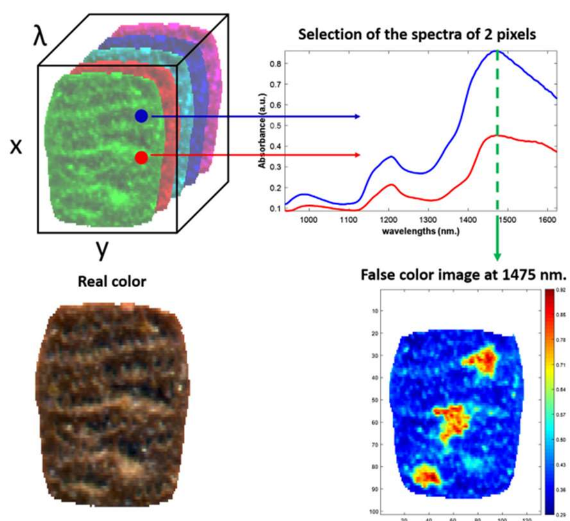

Figure 1 Image of a cookie captured with a hyperspectral camera in the wavelength range of 940 - 1600nm **[3]**

2.2 Hardware Design

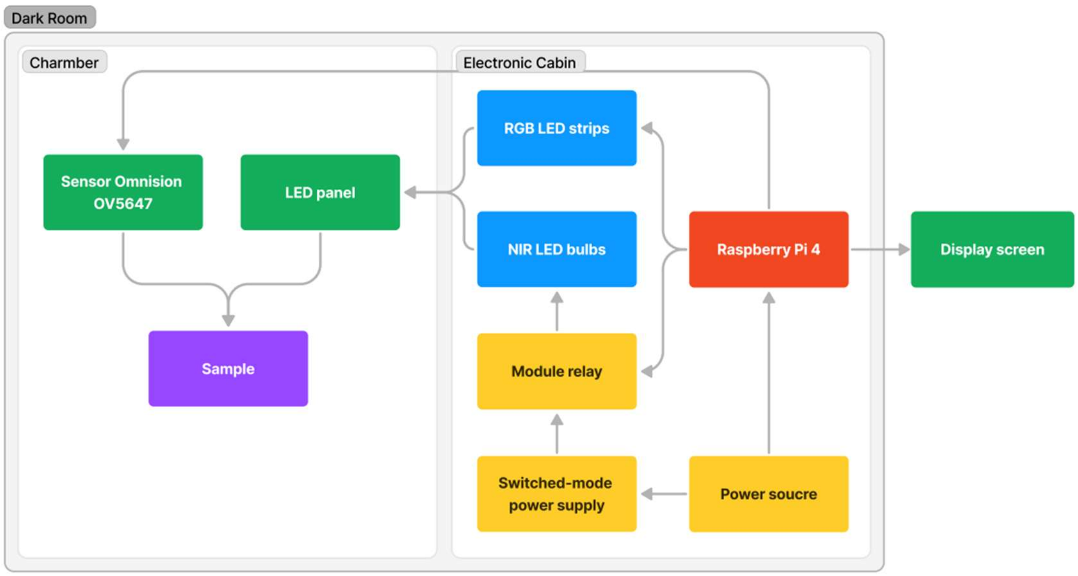

Figure 2: Diagram of multispectral imagery system

The multispectral imaging prototype's scheme is shown in *Figure 2*. The Dark Room is packed with all the necessary components (light isolated box). The Dark Room is divided into two separate rooms. The sample is taken in the Chamber, which has all of its walls painted black to minimize the amount of reflection light surrounding the sample. Moreover, the system core is stored in the Electronic Cabin. It all adds up to a portable capture system.

The system operates follow the *Figure 2.* One at a time, specific wavelength LEDs are individually illuminated, and for each flash, a sample is simultaneously taken with a Raspberry Camera

a) Main controller: Multispectral system uses Raspberry Pi 4 model B 4Gb, which serves as the core instrument, to control the whole system. It is a low-cost processor that can process with high capabilities, thus using it suitable for image acquisition. Furthermore, it accommodates a number of communication protocols allowing data transfer between the device and an external computer.

b) Display: The display screen is not contained in the Dark Room. However, it is an external instrument for the main system, connected to the primary hardware via an HDMI connection. With no need to move or remove any components, the display makes it simpler for the user to interact with the internal system.

c) Camera sensor: The image is acquired by using the micro-camera with the sensor Sony IMX219. This camera device is connected through serial interface bus, and is installed in the center of the led panel to capture sample under even illumination *Figure 4*. *Figure 3* shows the spectral sensitivity of this sensor. With the peak quantum efficiency of red is at 602 nm, quantum efficiency of green is around 542 nm and quantum efficiency of blue is around 453 nm. In which, quantum efficiency is the measure of the effectiveness of an imaging device to convert incident photons into electrons.

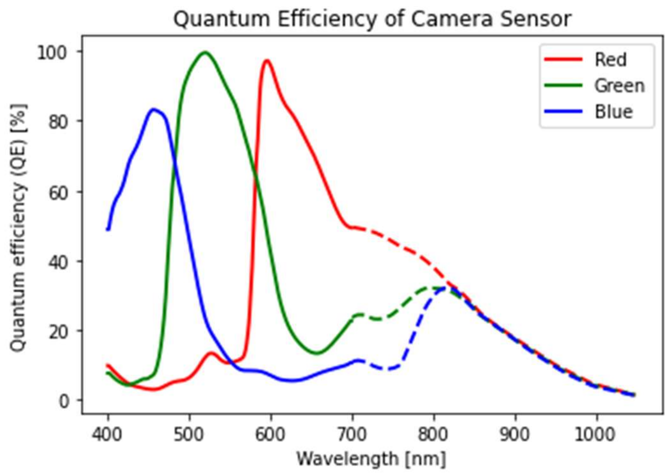

Figure 3 Quantum efficiency of camera sensor **[4]**

Besides, the technical specifications of the camera sensor, there are some adjustments come from the internal setting. Similar to regular camera, this model also follows the basic rule of photography. Three fundamental settings are ISO, aperture and shutter speed.

- ISO: Is international unit of measurement for a digital sensor's light sensitivity. In this work, Despite the fact that the sample is placed in a light-isolated environment, the camera is set to ISO 100. The box is perceived as a small studio that only contains one object at a time. As a result, because the flash, which is an LED system, focuses only on the sample, increasing the ISO will burn the image.
- Aperture: The aperture blades on a camera's lens regulate how much light is let into the lens. Depth of Field is also related to aperture (DOF). The multispectral model's height is 35cm, which is relatively low. As a result, the aperture needed to be appropriately set to avoid blurring the main object.
- Shutter speed: The duration of the lens's opening, which allows a certain volume of light to enter the sensor, is determined by the shutter speed. Under illumination of red, green and blue light, the shutter speed is set to 1s.

The operation occurs flow the diagram in *Figure 2* above. One at a time, specific wavelength LEDs are individually illuminated, and for each flash, a sample is simultaneously taken with a Raspberry Camera.

d) Led panel: The Led panel is the combination of RGB led strips and NIR led bulbs. The diameter of the LED panel is 40cm, which is fit with the length of the carputer chamber to produce uniform illuminate condition. Total 400 LEDs (200 RGB led and 200 NIR led) is arranged in a concentric circle to avoid shadows while getting image acquisition as shown in *Figure 4* [5], and *Figure 5* shows the connection schematic of RGB led and NIR led. Where an RGB led strip WS2812B is wired directly and is receiving signal from a Raspberry Pi. Meanwhile, the NIR led is indirectly connected, but it is connected to the relay, which is connected to the main processor.

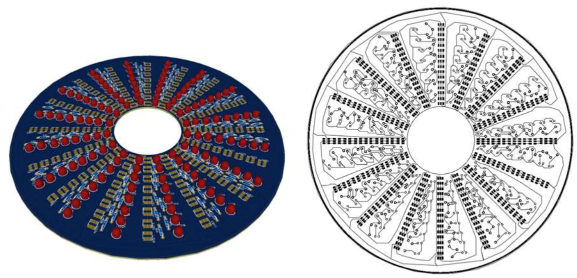

Figure 4 3D panel RGB led and NIR led (Left), circuit schematic of RGB led and NIR led (Right)

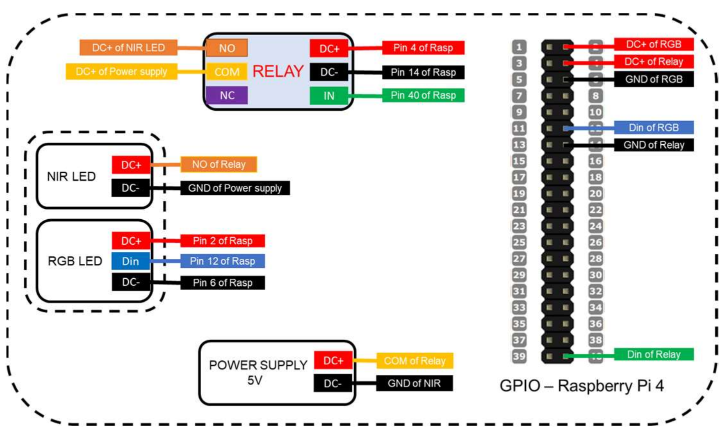

Figure 5 GPIO Connection

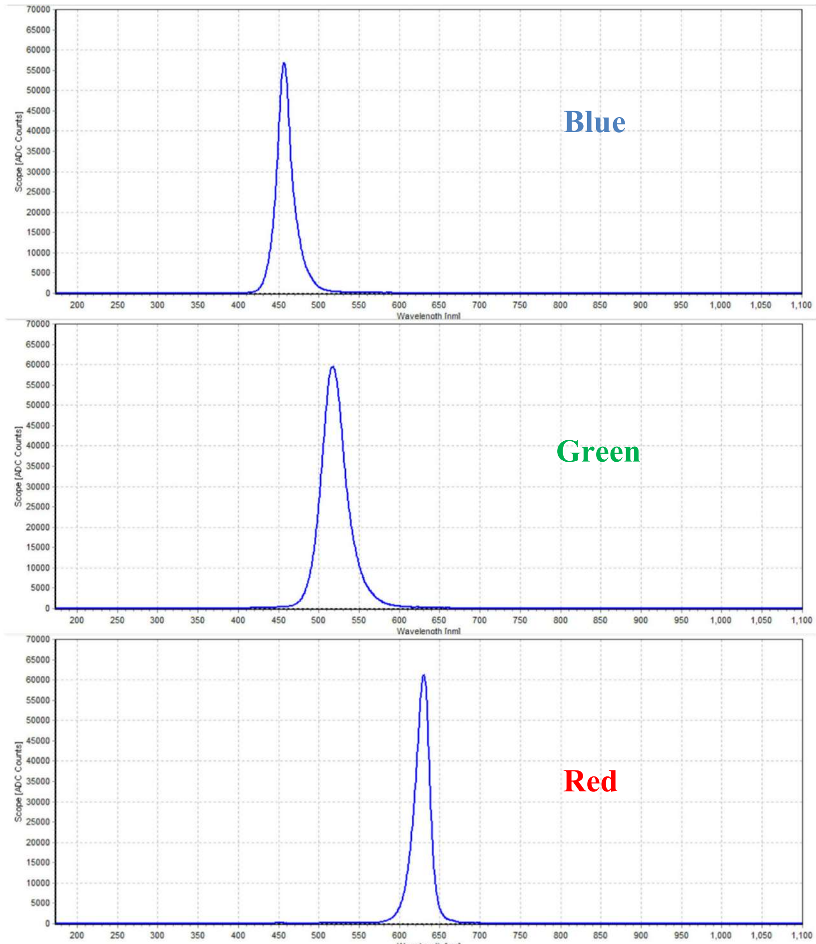

Figure 6 Wavelength peak of red, green and blue led

Figure 6 illustrates the wavelength peak of RGB led strips as measured by a spectrophotometer. In order to enhance the received signal and optimize accuracy, it is essential to match the wavelength peak of each red, green, and blue color with its corresponding quantum efficiency peak. Since the higher the quantum efficiency is, the more electrons are transformed, which increases the received signal after electrons are digitized. *Table 3* presents the comparison.

	Quantum efficiency of camera sensor	**Led wavelength**
Red	600 – 620 nm	620 – 625 nm
Green	530 – 550 nm	522 – 525 nm
Blue	450 – 460 nm	465 – 467 nm

Table 3 Comparison between quantum efficiency of camera sensor and led wavelength

3 Results and Discussion

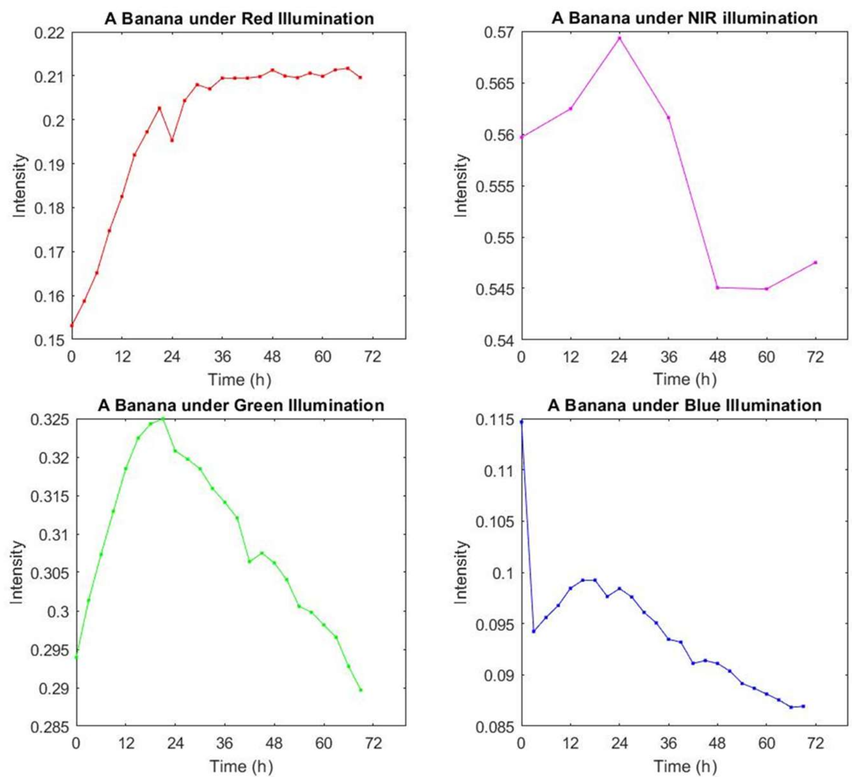

Figure 7 Banana's colors trend in 72 hours

Figure 7 illustrates the changes in reflectance intensity at four different illumination conditions of banana from unripe stage to ripe stage. Overall, banana under green, blue and near-infrared illumination decreased, while the intensity of red channel significantly increased in the period of time. In the red, green and blue channels examined the banana in 72 hours, and shoot every 3 hours a part. Meanwhile, the banana capture in near-infrared wavelength shoots every 12 hours a part. The increase in red channel can explain by the change in color (green to yellow). This also can explain why green and blue intensity increase through the period of time. Near-infrared channel decrease due to the increase in water since water absorb infrared light. Besides, there are some fluctuations in the graph, because the unstable received signal while taking image.

In summary, the multispectral technique is available to examine food quality. Comparing to hyperspectral, this technique can develop and apply to real-time evaluate since each operation take under 1 minutes. Even though, the output appears some fluctuation but these faults can be fix by stabilize the capturing system, preprocessing image and enhance the evaluation algorithm. Moreover, the intensity of illumination can be considering to improve the received signal. This Multispectral Camera Model have ability to develop for food industry in near future.

4 Conclusions

This study builds a first cheap prototype model to evaluate food quality, which can support the food industry in detecting irregular product by luminate the sample with multi-wavelength. This model has met several criteria such as simple setup, affordable price and portable. The result shows the trend of changing in the food properties under four illuminate condition in VIS-NIR band, instead of using invasive technique which damaged the product.

5 Acknowledgments

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References

1] Jarmo T. Alander, Vladimir Bochko, Birgitta Martinkauppi, Sirinnapa Saranwong, and Timo Mantere, "Jarmo T. Alander, Vladimir Bochko, Birgitta Martinkauppi, Sirinnapa A Review of Optical Nondestructive Visual and Near-Infrared Methods for Food Quality and Safety," *International Journal of Spectroscop,* 2013.

2] Wen-Hao Su and Da-Wen Sun, "Multispectral Imaging for Plant Food Quality Analysis and Visualization," *Comprehensive Reviews in Food Science and Food Safety,* vol. 17, 2018.

3] J. M. Amigo, Hyperspectral Imaging, vol. 32, Data Handling in Science and Technology, 2020.

4] H. Rhodes, D. Tai, Y. Qian, D. Mao, V. Venezia, Wei Zheng, Z. Xiong, C.Y. Liu, K.C. Ku, S. Manabe, A. Shah, S. Sasidhar, P. Cizdziel, Z., "The Mass Production of BSI CMOS Image Sensors," Omnivision Technologies, Inc. (OVT) .

5] Nuria Lopez-Ruiz, Fernando Granados-Ortega, Miguel Angel Carvajal, Antonio Martinez-Olmos, "Portable multispectral imaging system," *Sensor Review,* vol. 37, no. 3, pp. 322-329, 2017.