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Web Camera-Based Spectrometer System Precision Testing in Wavelength Measurement

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Abstract. A spectrometer is a device to produce the wavelength spectrum of an object. By applying existing technology, we designed a simple web camera-based spectrometer with a DVD piece as dispersion. This study aims to develop a laboratory-scale spectrometer for learning and research facility. To validate the spectrometer, we examined the precision. The input of the system is a light source derived from LED lights of various colors. The method used is to compare the measurement results with the existing wavelength literature. The spectrum wavelength was calculated accurately by an installed Theremino spectrometer software on the PC after the light passing through the web camera and the DVD piece. The wavelength value of the measurement results is processed to obtain the system's precision value. The precisions obtained are red 0.489 %, green 1.287 %, and blue 1.855%, which are relatively opmizing result for the simple laboratory's scale spectrometer.

INTRODUCTION

Each color has a different wavelength. When light is bent on a diffraction grating or prism side, different wavelengths of light will be bent to different degrees, this causes the wavelength value for each color will be different. To measure the wavelength required a measuring instrument, namely a spectrometer. A spectrometer is a tool that is applied to measure and produce a spectrum of wavelengths from an object [1].

Along with the development of technology as it is today, it is easier to design a system with the same function but with a simpler method, one of which is designing a spectrometer system using a web camera and DVDs as dispersing agents. In general, spectrometers use a prism to separate a mixture of wavelengths into their component lengths. But in this design uses DVD chips as a dispersion in the spectrometer system.

This web camera-based spectrometer is designed to determine the wavelength value of each color with near-zero precision. Because a good precision value is close to zero. The system precision value is obtained from the system test on the resulting wavelength value. The resulting wavelength will be compared with the literature for visible light and ultraviolet light, namely 400-800 nm for visible light wavelengths and 200-400 nm for ultraviolet light wavelengths [2].

This web camera-based spectrometer system is designed to evaluate the measurement of visible and ultraviolet light wavelengths with a system precision value that is close to zero so that the spectrometer can be used on a laboratory scale and can be used for learning media or other related research.

MATERIAL AND METHOD

The description of the system designed in this study consists of the functions and specifications of the designed system. The function of the designed system is to measure the wavelength value using a web camera-based spectrometer, so that the precision of the designed system can be known. The input of the system is a light source from an LED lamp, and the output of the system is a light spectrum and wavelength value. The specifications of the designed system are as follows:

1. Web camera as a medium to capture light which will be forwarded to the recorder.
2. Personal Computer (PC) as a display.
3. DVD chip as a diffraction grating.
4. Cardboard as a slit case.
5. Red, green, and blue lights are used as light sources.
6. Software using the Theremino Spectrometer.

System Design and Implementation Method

The working principle of the system is explained in a block diagram to make it easier to determine the software, hardware, and mechanical construction that helps the system work. The block diagram of the system is shown in Figure 1.

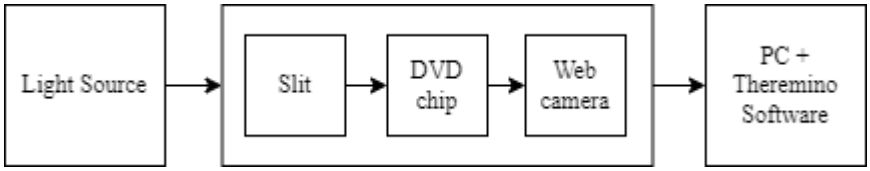


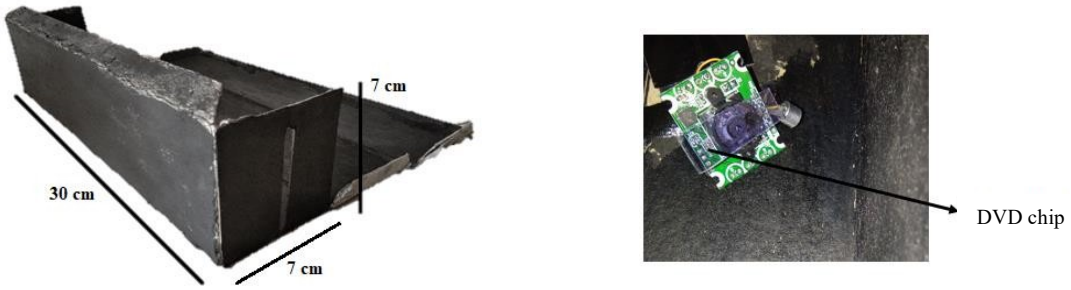
FIGURE 1. Web Camera-based Spectrometer System Block Diagram

Based on Figure 1., the way the system works begins by directing the light source from the LED lamp to the system. Light from the source will then go to the system by passing through the slit. Slit serves to focus light from the source to the system. The light that has passed through the slit will then pass through the DVD as dispersion and will then go to the web camera as a detector to display the measurement results on a PC that has the Theremino Spectrometer software installed to measure its wavelength. The input to the system is in the form of light from LED lamps and the system output is a color spectrum and wavelength value. The measurement results on the system are stored on a PC in the form of image data.

Mechanical and Hardware Construction Sub System

In system design, mechanical construction and hardware are used to support the work of the system. To simplify the design, mechanical construction in the form of a case is used to place the web camera. The case is made of paper that has a thickness of 0.2 cm. The case is in the form of a block with dimensions of 30 cm × 7 cm × 7 cm. The case is slit with a width of 5 mm in the vertical direction. The mechanical construction of the system is shown in Figure 2(a).

In the system, there is also hardware that is used to support the work of the system. The hardware in the form of a web camera that functions as a detector, with the specifications of the web camera used is video resolution: 640 × 480 pixels and Video format: 24-bit RGB. The web camera used is given a DVD chip as a diffraction grating. The light from the source will be captured by the web camera and will be forwarded to the PC as a recorder that will display the results of the wavelength measurement. In Figure 2(b). shown a web camera and a DVD chip on the system.



(a) (b)

FIGURE 2. (a) System Mechanical Construction; (b) Web Camera and DVD

Sub System Software

Web camera-based spectrometer system works by using software to determine the wavelength value. The software used is the Theremino Spectrometer. Theremino Spectrometer is software used to determine the color spectrum in visible light and UV light. This software calculates the intensity of light that comes at each pixel from the camera. The camera does not need to distinguish the colors of the photons collected, what matters is the intensity [3]. In Figure 3. The measurement results from the Theremino software are shown.

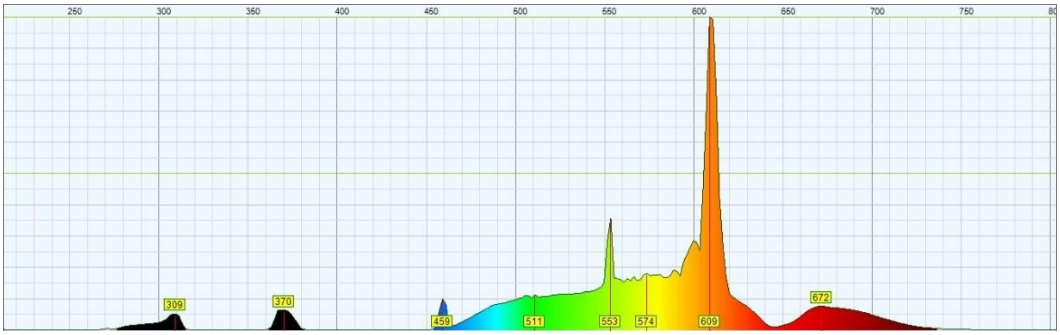


FIGURE 3. Measurement results by Theremino software

According to Figure 3, the Thremino software will measure the wavelength of light transmitted by the webcam. The measurement results in the form of a color spectrum and wavelength values will be stored on the PC.

System Testing Method

System testing begins by calibrating the system. Calibration is done on the Theremino software by directing the light source with a white light on the slit so that the light will be received by the web camera and will be measured by the Theremino. The Theremino software will display the color spectrum and wavelength values. The Theremino has a Trim Point to adjust the spectrum when calibrating. The Trim Point value on the Theremino is 436 nm for the blue spectrum, and 546 nm for the green color [3]. If the resulting spectrum is by the Theremino software specifications, then the calibration is successful and can be tested with different colors.

After the system is calibrated, the test is continued by determining the color spectrum for red, green, and blue, using LED lights of the same color. The test is done by directing the light source at the system, and the system will measure the wavelength. The test was carried out 10 times for each color. And the measurement results, color spectrum, and wavelength values are stored on a PC that has the Theremino Spectrometer software installed for further analysis of the precision values.

RESULT AND DISCUSSION

Tests were carried out on red, green, and blue lights with 10 times testing for each color. The measurement results produce a color spectrum and wavelength value. In Figure 4, the color produced by the testing system is red in the first test.

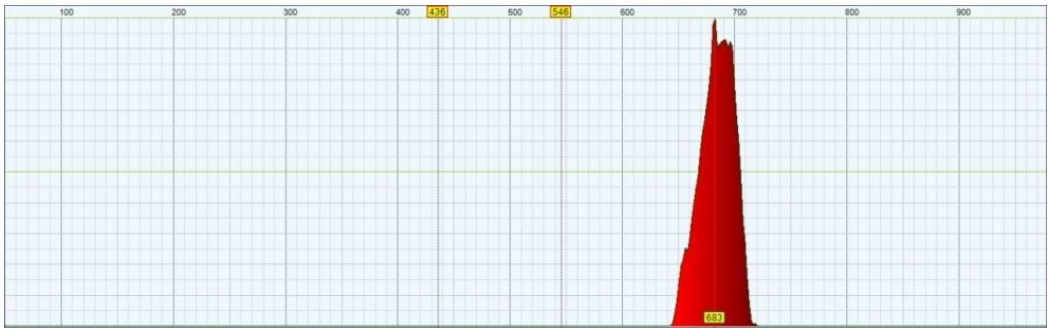


FIGURE 4. Color spectrum and wavelength value of red color test

In Figure 4., the color spectrum and wavelength values of the system test results are shown in red during the 1st test. The wavelength value generated by the system is 683 nm. This value is derived from literature values for the wavelength of red visible light, 610-750 nm [4]. The average wavelength measurements of red, green, and blue in the system are shown in Table 1.

TABLE 1. Average Wavelength

No	Color	Average Wavelength (nm)
1	Red	683,1
2	Green	543,4
3	Blue	463,6

Table 1. shows the average value of the measured wavelength on the web camera-based spectrometer system. The resulting wavelength for the system for red is 683.1 nm; green 543.4 nm; and blue is 463.6 nm. The results obtained by the system are by the literature on the wavelength of the visible light region with red color 610-750 nm, green 500-560 nm, and blue 435-480 nm [4].

The results of the system test with the output in the form of a color spectrum and a wavelength value are then processed to obtain a system precision value for the resulting wavelength. The test results on the sample were carried out 10 times to determine the system precision value. The system precision is calculated for each color tested by using the precision formula in Equation (1).

$$precision\ (\%) = \frac{|(mean\ value) - (i-th\ measurement\ value)|}{mean\ value} \times 100\% \quad (1)$$

By performing calculations on the results of measuring the wavelength of each color, system precision values for each color are obtained, as shown in Table 2.

TABLE 2. System Precision Value

No	Color	Precision (%)
1	Red	0,489
2	Green	1,287
3	Blue	1,855

In Table 2., the system precision value for wavelength measurement produces a value close to zero. The precision results of the red, green, and blue colors are 0.489%, 1.287%, and 1.855%, respectively. The results of the calculation of the precision of the system on the measurement of the wavelength obtained are relatively small and close to zero. Therefore, the system has good accuracy.

With the precision value obtained in the system, the system can be used to analyze the concentration of glucose solutions or other solutions. Because in general a spectrometer can be used to measure the concentration of a solution by measuring the absorbance at a wavelength using the Lambert-Berr law [2]. With the obtained wavelength, it can be measured the concentration of a solution.

CONCLUSION

Based on testing and analysis of a webcam-based spectrometer system design, the system produced good precision values for the colours tested (i.e., red, green, and blue). The system precision values for red, green, and blue are 0.489%; 1.287%; and 1.855%, respectively.

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REFERENCES

1. I. Novianty, *Vis-Nir Reflectance Spectroscopic Analysis to Determine the Maturation Process of Strawberries*, Department of Physics, Faculty of Mathematics and Natural Sciences, IPB University, Bogor, (2008).
2. Dachriyanus, *Spectroscopic Structural Analysis of Organic Compounds*, Institute of Information and Communication Technology Development of Andalas University, Padang, (2004).
3. Theremino. (n.d.), *Theremino Spectrometer*, Retrieved from Theremino: https://www.theremino.com/en//
4. E. Triyati, "Ultra-Violet and Visible Light Spectrometers and Applications in Oceanology", *Oseana*, X(1): 40-41, (1985).