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Histogram Characterizations of Infrared Images Captured By a Modified Digital Camera

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Abstract

The histogram of image data, which exhibit their respective pixel's value distributions, represents the specific characteristics to acquire the expected associated information. The infrared beams range the wavelengths from 0.78 μm to 1000 μm which substantially longer that the visible light, which can be detected by an ordinary digital camera with an addition of a visual light blocking filter.

The colors of the obtained image basically associated with those received by the camera's R, G, B sensors, which in turn are expected to contain the relevant infrared radiation energy from the caught objects.

The results of our experiment show that different visible light filter modifies the histogram patterns significantly, but with similar basic pattern.

Keywords: histograms, infrared light, filter.

Introduction
Background
Temperature is the measure of every object's thermal energy. The temperature measurement methods for objects are based on some temperature scales. Any object heat measurement is based on the thermal energy transferred from the object to the sensor, directly or non-directly via the infrared emission which is captured from a distance by special sensor. The data received from a non-contact temperature

measurement appear as an image which represents the temperature distribution of the monitored object.

Naturally, infrared emission is related to the radiation heat transfer, which as an electromagnetic wave having wavelengths between the visible light and the microwave. Therefore, if we use different filters for the visible light, we could see the differences in the histogram patterns of the images spread R, G, and B data which bear the information infrared image captured.

The objectives of the research

The objectives of the research is to require some information about objects captured by an ordinary camera which is operated in infrared spectrum range based on the distribution patterns of the respective R, G, and B histograms.

Literature Review

Today's digital cameras rely basically on their solid-state light sensors which generally sensitive to a wide ranges of electromagnetic wave spectrum beyond the visible band. Replacing the infrared stopping filters with some visible light ones, we have investigated the resulting captured images by these cameras.

The underlying theory of the absorption of the radiation energy by a sensor is mechanical equivalent of heat. Based on this theory, which is confirmed by laboratory experiment, mechanical energy can be in the form of kinetic and/or potential energy, while the thermal energy normally appears as radiation phenomenon. Sensors for the radiation energy convert it into the kinetic energy of the electrons. This electrons mobility in turns generated the output voltage and/or current of the sensor.

Fundamental of radiation

The mathematics used to explain the main step of modern thermograph radiation theory. The Planck quantum theory assumes that the radiation is developed by a packet of discrete energy which called photon or quanta. The value of quanta depends on the radiation wavelength. The total energy per quantum, E, received by multiple with Planck constant, h = 6.6256 x 10^{-34}, and radiation, υ, in cycle per second. In 1905, Albert Einstein presented quanta is particle that move in light velocity, c = 2.9979 x 10^{8} m/s. If the photon moves in light velocity, then its compliance with relativity theory, $E^2 = c^2p^2$, and momentum each photon $p = E/c = h/\lambda$, photon frequency could be determine by divide light velocity with particle wavelength $\upsilon = c/\lambda$. Substitute to momentum, have equation:

$$E = h\upsilon = hc/\lambda \tag{1}$$

Equation (1) shows that value of energy emission depend on wavelength or frequency. Shortest wavelength has highest energy per quantum photon (Fig.1). IR wavelength has range of between 0.78 μm to 1000 μm. IR area divided in three areas, i.e. near infrared (0.78-3.0 μm); middle infrared (3-30 μm); and far infrared (30-300 μm). Human eyes only can see little fraction of energy spectrum that emission by sun (visible light) [1]. However, if human wants to "see" IR radiation emission for all part (organic and an-organic), then effectively is conduct in the dark condition. Although can't see by human eyes, but IR radiation could detection as warm on the skin, and even IR radiation of object that have temperature lower than ambient could capture because sense more cool [1, 5, 7].

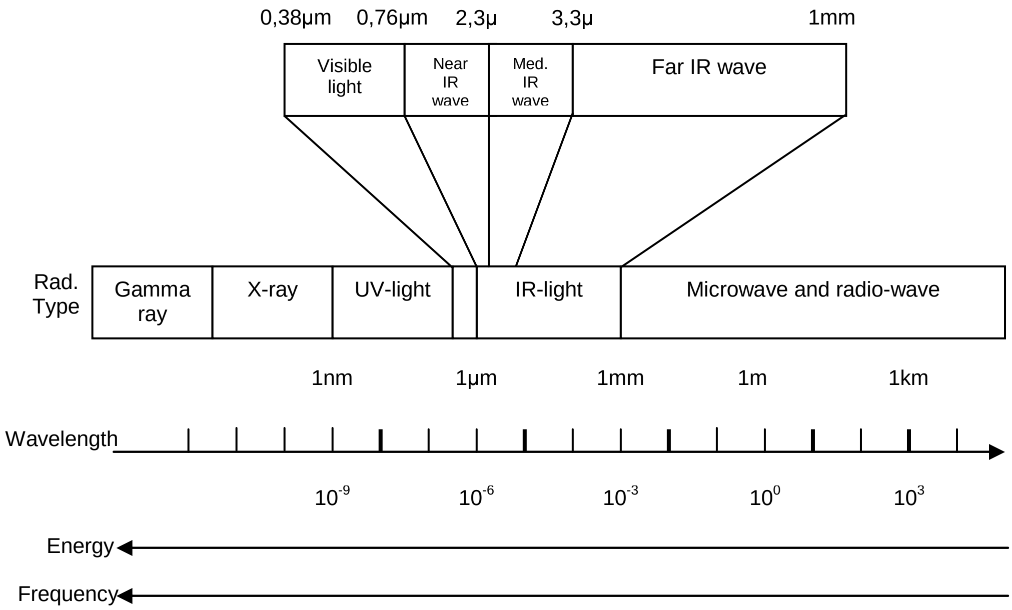

Figure 1: Electromagnetic wave spectrum.

Image Processing

Image processing is a process to search information that contain in an image. Fig. 2 shows block diagram overall main image processing system. Information that content in an image can big amount and various, depend on subject (subjective). Searching information, original image must be preprocessing, for enhance this image, because imperfect acquisition system or receiving data and have noise.

The opposite with preprocessing part, in the end image processing have display, storage, and/or giving processing product to direct subject or transmitted to other place [3, 4]

Developing image processing technique is so far, from software or hardware aspect. Beside that, range of image acquisition is so wide, i.e. using sensor-sensor that able to capture frequency or IR wavelength. If in visible light area divided three frequency areas, then in IR area divided in 12 areas.

Histogram is the basic of processing technique in the multi spatial range. Histogram manipulation is effectively used to enhance an image. Image histogram is histogram grey level with range [0, L-1] with discrete function $h(r_k) = n_k$, when r_k is grey *k-th* and n_k is image value pixel in grey level r_k (Gonzalez, 2008). That is can used to define histogram R, G, and B.

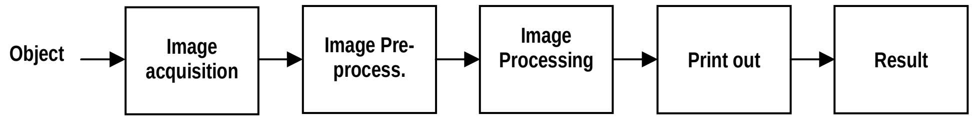

Figure 2: Block diagram image processing system.

Absorber filter

Absorber filter use to capture infrared light, because the absorber filter can absorb visible light [6]. Absorber filter make from celluloid film that burn in the sunlight [2]. Other absorber filter that fabricated is Hoya R72 and Hoya RM90. Those filters have characteristic table that can show in Figure 3 (Hoya R72) and Figure 4 (Hoya RM90). Figure 3 shows filter Hoya R72 can pass light with range wavelength 680nm—800nm, so it hasn't use for monitoring an object that have wavelength longer than 800 nm. Filter Hoya RM90 can use for capturing light with wavelength 640nm—2400nm (near-infrared until middle infrared area) (Fig. 4).

Infrared Transmitting Filter

Catalog Thickness t= 2.5 mm | Reflection Factor P_d=0.911 | Diagram-1

R-72

Transmittance (T) & Internal Transmittance (τ) units:(%)

λ_{nm}	200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350	360	370	380	390	400	410	420	430	440
T																									
τ																									
λ_{nm}	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630	640	650	660	670	680	690
T																								$4\cdot10^{-3}$	.05
τ																								$4\cdot10^{-3}$	.05
λ_{nm}	700	710	720	730	740	750	800	850	900	950	1,000	1,100	1,200	1,300	1,400	1,500	1,600	1,700	1,800	1,900	2,000	2,100	2,200	2,300	2,400
T	1.1	12.4	38.5	63.6	78.2	85.2	90.8																		
τ	1.2	13.6	42.3	69.8	85.8	93.5	99.7																		

Figure 3: Characteristic Hoya R72.

Infrared Transmitting Filter

Catalog Thickness t= 2.5 mm | Reflection Factor P_d=0.904 | Diagram-1

RM-90

Transmittance (T) & Internal Transmittance (τ) units:(%)

λ_{nm}	200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350	360	370	380	390	400	410	420	430	440
T																									
τ																									
λ_{nm}	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630	640	650	660	670	680	690
T																				$1\cdot10^{-3}$	$2\cdot10^{-3}$	$4\cdot10^{-3}$	$6\cdot10^{-3}$	.01	.02
τ																				$1\cdot10^{-3}$	$2\cdot10^{-3}$	$4\cdot10^{-3}$	$7\cdot10^{-3}$	.01	.02
λ_{nm}	700	710	720	730	740	750	800	850	900	950	1,000	1,100	1,200	1,300	1,400	1,500	1,600	1,700	1,800	1,900	2,000	2,100	2,200	2,300	2,400
T	.03	.06	.10	.17	.28	.46	3.8	16.4	38.1	59.4	74.5	81.8	86.2	87.1	87.2	87.3	87.5	87.4	87.2	87.6	88.0	87.5	86.8	86.1	85.3
τ	.03	.07	.11	.19	.31	.51	4.2	18.1	42.1	65.7	82.4	90.5	95.4	96.4	96.5	96.6	96.8	96.7	96.5	96.9	97.3	96.8	96.0	95.2	94.4

Figure 4: Characteristic Hoya RM90.

Research Methode

Equipments of this research are: digital camera, object, absorber filter visible light lens (made by self, Hoya R72, and Hoya RM90), personal computer (PC), software MatLab V 6.2, and software Ms-Office 2003.

Research's steps are:

a. Developed research's equipment (Figure 5),
b. Captured object using digital camera that installed absorber filter lens,
c. Transferred object that recording in memory card camera to PC,
d. Processed captured images in order that we have image histogram red, green, and blue (RGB) level.

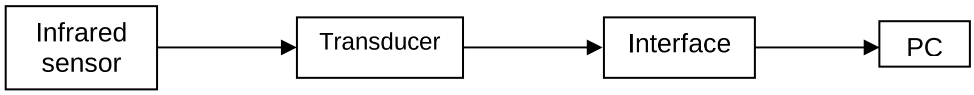

Figure 5: Equipment Research Circuit.

Result of the Research

Results of this research are images histogram (Fig. 6—Fig.11) for same object at the same condition and table peak RGB level (see Table 1).

Image acquisition is conducting in dark room, using digital camera, without flash, ISO 100. This condition is basic condition using are references for successive data.

Figure 6 shows image histogram RGB without absorber filter lens (i.e. visible light histogram) has peak of red level intensity $7x10^4$ on byte 55, peak of green level intensity $15x10^4$ on byte 20, peak of blue level intensity $12.5x10^4$ on byte 20.

Figure 7 shows image histogram RGB of digital camera equipped with single absorber filter lens (made by researcher) has peak of red level intensity $2x10^4$ on byte 255, peak of green level intensity $15x10^4$ on byte 25, and peak of blue level intensity $12.5x10^4$ on byte 255.

Figure 8 shows image histogram RGB of digital camera equipped with double absorber filter lens (made by researcher) has peak of red level intensity $2.1x10^4$ on byte 255, peak of green level intensity $0.65x10^4$ on byte 40, and peak of blue level intensity $0.85x10^4$ on byte 255.

Figure 9 shows image histogram RGB of digital camera equipped with single absorber filter lens (made by researcher) has peak of red level intensity $1.55x10^4$ on byte 255, peak of green level intensity $0.65x10^4$ on byte 50, and peak of blue level intensity $0.85x10^4$ on byte 255.

Figure 10 shows image histogram RGB of digital camera equipped with filter Hoya R72 (R72). R72 passes light with wavelength between 680nm—800nm. Figure 10 shows image histogram RGB has peak of red level intensity $16x10^4$ on byte 255, has peak of green level intensity $7x10^4$ on byte 10, and has peak of blue level intensity $5x10^4$ on byte 15.

Figure 11 shows image histogram RGB of digital camera equipped with filter

Hoya RM90 (RM90). RM90 passes light with wavelength between 640nm—2400nm. Figure 11 shows image histogram RGB has peak of red level intensity $10x10^4$ on byte 255 peak of green level intensity $4x10^4$ on byte 10, and peak of blue level intensity $4x10^4$ on byte.

Fig. 7, Fig. 8, Fig. 9, and Fig 11 have similar form, differences only the value of peak and intensity each level. Fig. 11 shows that the histogram has highest peak intensity, so that information that Hoya RM90 tends passed image with red level. Histogram in Fig. 7—Fig. 9 shows intensity red level have peak same relatively ($1.55x\ 10^4$—$2.1x10^4$) on byte 255, but in blue level have peak between $0.7x10^4$ to $0.85\ x\ 10^4$255 on byte 255. These show image captured with digital camera equipped absorber filter made by researcher passes red level and blue level, but similar with RM90.

Fig. 7—Fig. 11 show cutting intensity red level consequence filtering visible light after filter lens equipped on the digital camera, so its to influence number of pixels and intensity red level image object. Using absorber filter lens we have result different pattern image histogram RGB level if comparing with digital camera without filter.

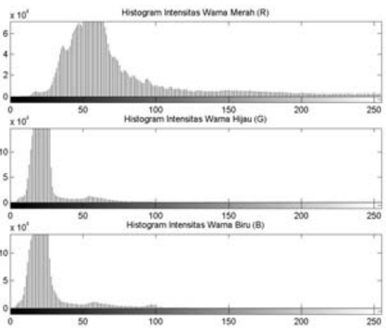

Figure 6: Image histogram RGB without absorber filter lens.

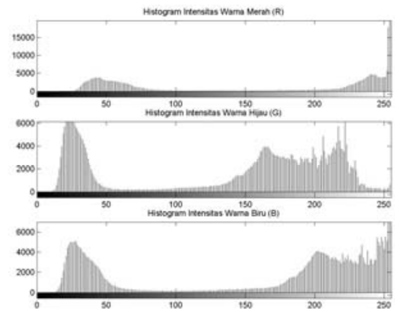

Figure 7: Image histogram RGB with single absorber filter lens.

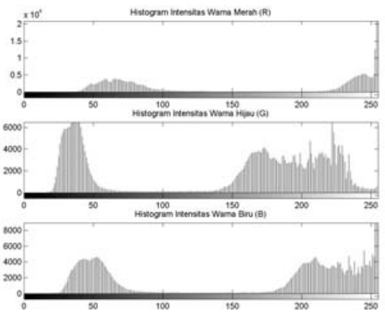

Figure 8: Image histogram RGB with double absorber filter lens.

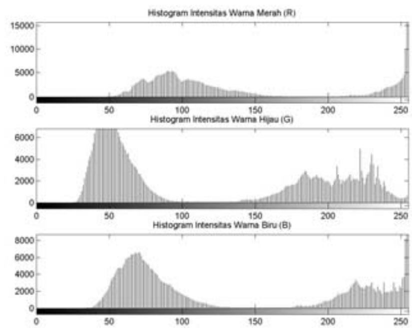

Figure 9: Image histogram RGB with six absorber filter lens.

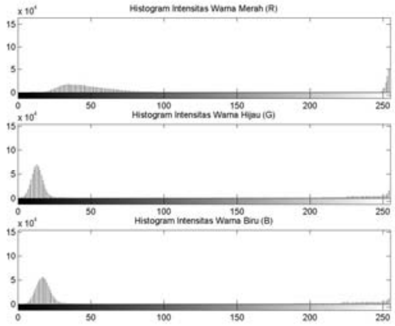

Figure 10: Image histogram RGB with absorber filter lens Hoya R-72.

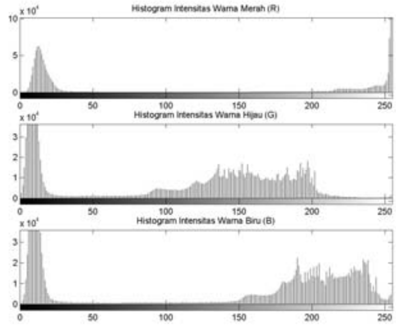

Figure 11: Image histogram RGB with absorber filter lens Hoya RM-90.

Table 1: Peak red level (R), green level (G), and blue level (B).

No.	Object	Peak					
		Position			Height (x10^4)		
		R	G	B	R	G	B
1	Without absorber filter lens	55	20	20	7	15	12.5
2	Single absorber filter lens	255	25	255	2	0.6	0.7
3	Double absorber filter lens	255	40	255	2.1	0.65	0.85
4	Six absorber filter lens	255	50	255	1.55	0.65	0.85
5	Hoya R72	255	10	15	6	7	5
6	Hoya RM90	255	10	10	10	4	4

Conclusion and Suggestion

Conclusion

The result shows that different absorber visible light filter modifies the histogram pattern significantly different.

Suggestion

This research could be continuing with research about infrared light with other infrared devices.

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