Detection air pollution based on infrared image processing

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Detection air pollution based on infrared image processing

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Abstract

This paper proposes a method of detecting air pollution in a region using image processing techniques. The image used is the infrared image that obtained using a modified digital camera by mounting the SRS filter. Image processing technique used is to utilize wavelet transformation. Pollutants are detected based on the average number of white pixels that appear on the image. This white pixel appears due to the reflection of the wavelength of the pollutant that hits the sensor on the camera. From the results of the proposed method detection is known that the highest pollution occurs in 12.00 which is the busiest traffic time and the lowest pollution occurred in 08.00 where the traffic passing through the area has not been crowded.

Keywords: *detection, infrared image, pollution, SRS filter, wavelet*

1. Introduction

Air pollution is a condition of air contaminated by chemicals, substances/particles, and other biological materials that could endanger the health of living beings and other organisms. Air pollution could be caused by motor vehicle fumes, a factory fumes or the forest fires. The negative impact of air pollution on health is could be caused breathing problems or inflammation of the respiratory tract, skin health disorders, and stress. This negative impact is what drives the need for research about air pollution detection. This research aims to identify the presence of air pollution in one place by using digital image processing in real time. Image processing in this research conducted in the frequency domain. Therefore, the previous done the transformation of the spatial domain to the frequency domain using wavelet transforms. After the image transformation results obtained, hence can be done analysis further. The use of image processing basically utilizes the electronic visual sensor (camera) which replaces the human visual system (eye). The advantages of the electronic visual sensor are to have a wavelength range that is larger than the human eye. In addition, an electronic visual sensor is also more sensitive in distinguishing the degree of intensity of each pixel of the image. By using image processing the little difference of the pixel intensity between pollutants and air through this sensor can be differentiated.

A lot of research about the detection of air pollution has been done before. Wang has been doing research about the rendering process of air pollutants based on image processing [1-3]. In contrast to the research conducted by Wang, this research uses wavelet transformation to detect air pollution from an infrared image. Joans has been used images diffusion process and ratio factor to analysis polluted images. The Infrared imagery-based research has been done before by doing image segmentation in infrared images to determine the environmental conditions [4]. The infrared image obtained by using SRS filters whose characteristics known from the previous research [5-7]. The SRS filter is a filter that transmits infrared waves made from cellulose films.The other research that has been done is the detection of indoor air pollution on wet or moist walls using a thermal camera [8]. This proposed research is done outdoors by taking infrared images using a camera. The other research that has been done is the detection of air pollution on satellite images [9-13].

The difference with this research is the method used. In this experiment, the image processing is done in the frequency domain while the research that has been conducted using the image processing in the spatial domain. Another difference is in the coverage area of the image based research has been done before by doing image segmentation in infrared

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images to determine the environmental conditions. The infrared image obtained by using SRS filters. The SRS filter (the name of creator) is a filter that transmits infrared waves made from cellulose films whose characteristics known from the previous research. This proposed research is done outdoors by taking infrared images using a camera. The difference with this research is the method used. In this experiment, the image processing is done in the frequency domain while the research that has been conducted using the image processing in the spatial domain. Another difference is in the coverage area of the image.

2. Research Method

Air pollution is a condition in which air is polluted by chemical or biological particles that can harm the health of living things. The particles that pollute the air are also called pollutants. In urban areas, sources of the pollutants come from vehicle fumes and industrial factory smoke. At low pollution levels, the number of particles in the outdoor air can reach 5,000-10,000 particles/cm^3. At high pollution levels, for example, when high traffic volume can reach 300,000-1,000,000 particles/cm^3 [14]. This particle size is very small namely less than 2.5 mm so the human eye cannot see it directly [15]. The existence of these particles can be detected using a digital camera. These particles will be captured by the camera as noise. The principle of pollutant detection using a digital camera is shown in Figure 1.

The previous research on the use of infrared images has been widely done. Sulistiyanti has been conducted research on infrared image enhancement [16, 17]. The infrared images can be used to obtain the thermal condition information of an object by performing a spatial filtering of an object [18-21]. Another research was to use an infrared image captured by digital cameras to determine isothermal calorimeter [22]. In addition, the other research used infrared images to determine the ignition point from the magnesium chip cutting temperature [23], and object discrimination [24]. Furthermore, practical applications for national security used this image processing [25].

In this research, the image was taken using a 5 MP digital camera mounted a SRS infrared filter. The usefulness of this filter is to pass the infrared light and to filter the other light. The image data were taken around the Bambu Kuning market, Bandar Lampung between 08:00 until 16:00 and intervals of data collected every 2 hours. The infrared images are images that obtained from a camera that uses filters to block visible light and allowed a near infrared light (infrared photography). The wavelength ranges used in infrared photography is about from 700 nm to 900 nm, shown in Figure 2. To get this image, the digital camera is modified by installing an infrared filter. The infrared filter used in this research is the SRS filter.

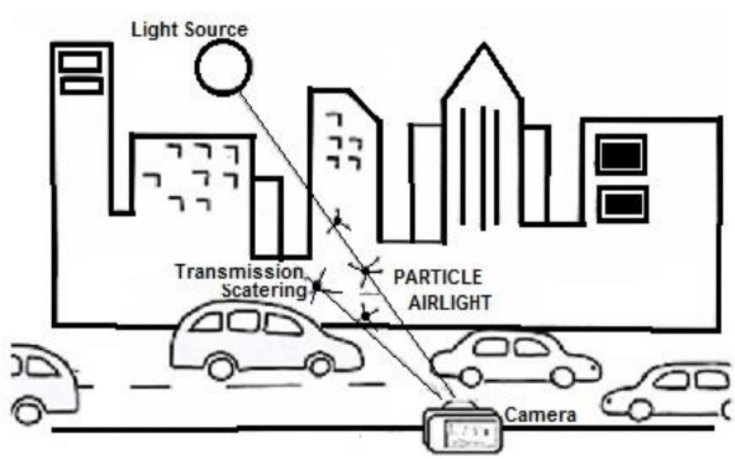

Figure 1. The radiance reaching the camera is the summation of the transmitted light from the object and light from the sun after scattering by particles

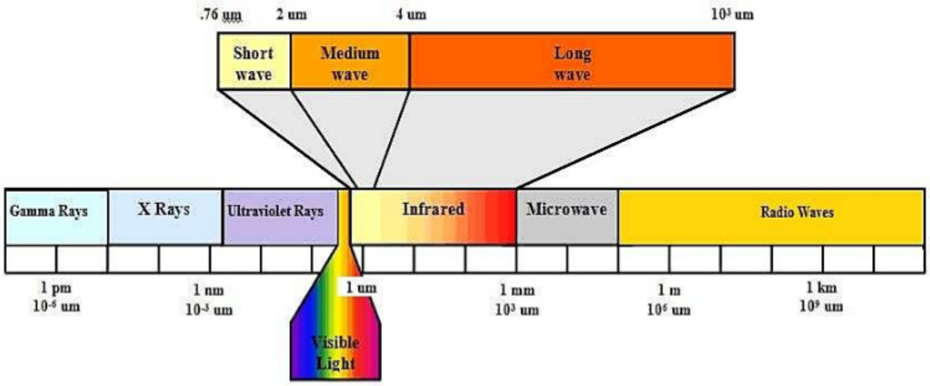

Figure 2. The wavelength range in photography

Then the captured infrared images are processed using image processing in the frequency domain, namely wavelet transform. The wavelet transform can be used as a multi-resolution analysis that can represent the time and frequency information of a signal. A signal whose frequency varies in time can be well analyzed using this transformation. In image processing, the wavelet transforms used are 2-D wavelet transforms. The image for image processing is represented as a 2-D matrix.

The decomposition process in the wavelet transform will attempt to divide the signal into two parts by the same number of sampling signals. These two parts are separated by two types of filters which have two different frequency bands, i.e. high-pass filter ($h[n]$) and lowpass filter ($g[n]$). After that the process is continued by modifying the signal based on the function of scale and time. This process repeatedly to determine the Discrete Wavelet Transform level and will affect the magnitude of the frequency band in each coefficient. The wavelet decomposition process is shown in Figure 3.

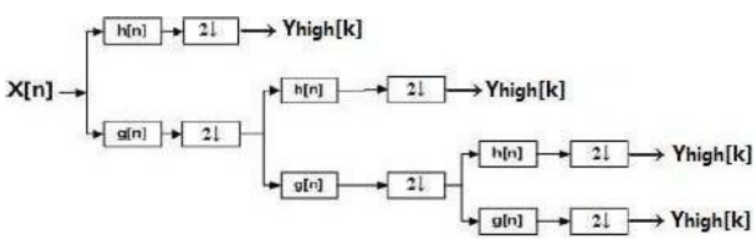

Figure 3. The wavelet decomposition

Decomposition process can be through one or more levels Mathematical, the one level decomposition is expressed by the following (1) and (2):

$$YHigh[k] = \sum_n X[n]h[2k-n] \quad (1)$$

$$YLow[k] = \sum_n X[n]g[2k-n] \quad (2)$$

Here $YHigh$ and $YLow$ are results from highpass filters and lowpass filters, $x[n]$ is origin signal, $h[n]$ is highpass filter, and $g[n]$ is lowpass filter. In the Haar wavelet, each step of the transformation always takes into account the wavelet coefficients and the average set. The equations for calculating an average a_i and Wavelet coefficients (c_i) are (3) and (4):

$$a_i = \frac{s_i + s_{i+1}}{2} \tag{3}$$

$$c_i = \frac{s_i - s_{i+1}}{2} \tag{4}$$

here s_i is the *i-th* data, s_{i+1} is the data after *i-th* data, s_{i-1} is the data before *i-th* data, a is the data average, and c is the wavelet coefficient.

3. Results and Analysis

The captured image results are shown in Figure 4. The image size obtained from the camera is 4 MP. The image is cropped with a size of 100×200 pixels on the area to be observed (region of interest/ROI), shown in Figure 5 respectively.

Figure 4. Results of capturing an image

(a) (b)

Figure 5. The position of the observed area in the research (a) original image and (b) the position of cropping

In this proposed method, infrared images of a RGB mode are converted into a grayscale to find out how much noise of the object. In this conversion process, the original image has a 24 bit pixel depth become to 8 bits. The next step is the image registration process. This process is done to get the same area on the different image. This process is done because the image is taken at different times so that there may be changes a camera position due to movement.

The use of cropping which has 8-bit image format is assigned wavelet transformation process and then done the decomposition process. The result of the decomposition process is shown in Figure 6. From the decomposition result, the intensity of the four images is summed to obtain the final image, shown in Figure 7.

The image of the summing of these intensities is segmented into 4 segments, 8 segments or 16 segments. From the final image is calculated the average intensity to obtain image data that represents the presence of pollutants. Calculation of the average intensity using (5):

$$I_{average} = \frac{\sum_{i=0}^{M-1}\sum_{j=0}^{N-1} I_{(i,j)}}{M \times N} \quad (5)$$

here M is the image width, N is the image height, and $I_{(i,j)}$ is the intensity of the(i,j) pixel.

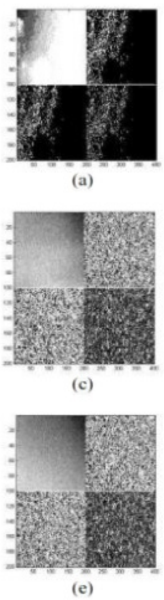

Figure. 6 The wavelet decomposition result in the image at (a) 08.00, (b) 10.00, (c) 12.00, (d) 14.00, and (e) 16.00

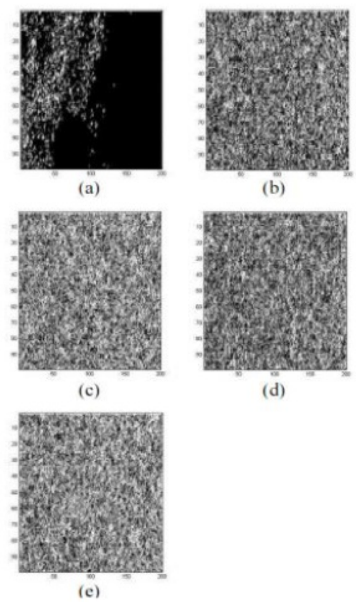

Figure 7. The summing result of the decomposition image at (a) 08.00, (b) 10.00, (c) 12.00, (d) 14.00, and (e) 16.00

The result value of the sum and average of the intensity for each segment and time is shown in Table 1. The minimal number of pollutants in the observed area occurred at 08.00 and the maximum number of pollutants occurred at 12.00. The area observed is the shopping area where the trade activity and the busiest traffic occurred in 12.00. In the observed area, the primary source of the pollutant comes from the smoke of vehicles passing through the area. At 08.00, traffic conditions in the area have not been crowded because the shops open at 09.00 so the condition of air pollution is still low. Similar pollutant detection results from the use of segmentation of 4 segments, 8 segments, and 16 segments, is shown by the graph in Figure 8.

Seen in Figure 8, in the morning (08.00) qualitatively produces images that look mostly dark, this means the air condition is still relatively clear. The black color declared a state of air condition that there are no pollutants while the color other than black is a pollutant because it is due to the wavelength reflections of the pollutants. Increased white pixels that indicate the presence of pollutants in the air in the observed area looks at 10.00-16.00. Increased air pollution is due to the increasing number of vehicles that pass through or has activities in the area.

The pollution peak occurs at 12:00 because at that hour the store employees use their time for activities in the outside because that time is a rest time. At 14:00 there was a decrease in pollution because traffic activity was not as busy as at 12:00. The increased of the pollution occurred again in 16:00 because ahead of the shops closed so that traffic vehicle activity of the buyers who leave a shop increased. CO2 measurement were carried out using a Combo IAQ meter at a location and the same hour proving that the highest levels of CO2 were at 12:00 and 16:00, shown in Figure 9.

This research proves that the more pollutant in the air, then the more noise arising in the image too, this phenomenon is shown in Figure 1. This noise appears from the reflection of the wavelength transmitted by pollutants that hitting the sensors in the camera. The wavelength of this pollutant is different from the wavelength reflected by the background object. This difference is that causes the occurrence of spots as if the noise.

Table 1. The Result Value of the Sum and Average of the Intensity

Clock	4 segment		8 segment		16 segment	
	Sum	Average	Sum	Average	Sum	Average
08:00	224592	112296	246000	12.3000	235024	117512
10:00	789156	39.4578	726477	36.3239	809631	404816
12:00	1003695	501846	898299	44.9150	912234	456117
14:00	821454	410727	742931	371466	721778	360889
16:00	927678	463839	776300	38.8150	815852	40.7946

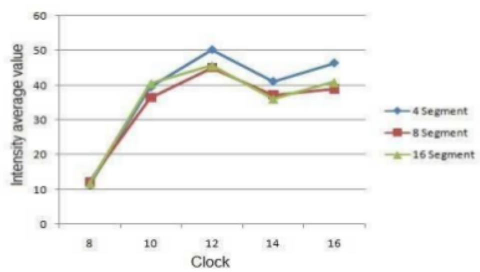

Figure 8. The average value of intensity for each segment

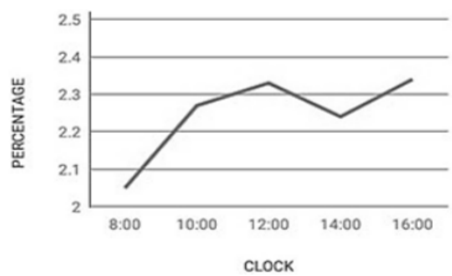

Figure 9. Trend of percentage CO_2 levels in the air using Combo IAQ meter

4. Conclusion

This paper proposes a pollutant detection technique on air pollution using Wavelet transforms. Using a wavelet transforms, the noise on the image can be well recognized so that it can be used to represent the presence of pollutants. The trends of an increase of the air pollution are obtained from the calculation data of the intensity average of the image in the observed area. This is in accordance with the condition that at 12:00 is the busiest traffic time resulting in maximum air pollution in the area.

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