Moving Average Method on Thermal Objects Acquired by Consumer Digital Camera

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Abstract--In this paper, an experimentation to enhance the visibility of hot objects in a thermal image acquired with ordinary digital camera is reported, after the applications of contrast stretching. The moving average techniques were used to suppress granular noises. Finally lowpass, median filtering as well moving average method were applied, where the later is best for suppressing granular noise and maintaining the intended thermal images.

Keywords: consumer digital camera, granular noises, moving average method.

A. Introduction

Consumer digital cameras are constructed to be most sensitive to visible light of wavelengths 400 to 700 nm. However, the actual range of the working sensors is beyond this range and covers the NIR as well as the UV wavelength proportionally. Therefore, it is worth looking into the possibility of modifying these cameras to gain thermal images.

To probe further the practicability as well as the usefulness of a consumer digital camera to obtain thermal images after some standard image preprocessing, viz. The histogram stretching to enhance their overall visibility, filtering to reduce the unwanted interference as well as to increase the noticeability of the residing objects of interest [1].

In this case, the objects of interest are those at temperatures higher than the background. Understanding that consumer digital cameras are manufactured to record objects which emit and or reflect only visual light, the photosensors are expected to give low output in the thermal electromagnetic radiation range.

Thermal images acquired with a modified consumer digital camera bear granular noises due to the overstretching of the naturally very low intensity levels. Therefore the research objective is to explore further and to find the appropriate image processing techniques to utilize the consumer digital cameras to acquire meaningful thermal images. To expose better the thermal objects of interest another nonlinear filters should be explored which do not demand complex or lengthy computations. Smoothing with moving average should be looked into experimentally.

B. The Underlying Theory

Today’s digital cameras rely basically on their solid-state light sensors which generally sensitive to a wide range of

Naskah ini diterima pada tanggal 27 September 2009, direvisi pada tanggal 2 Nopember 2009 dan disetujui untuk diterbitkan pada tanggal 1 Desember 2009

electromagnetic wave spectrum beyond the visible band. Removing the residing infrared stopping filter and replacing it with a visible light one, we are left with NIR images [2, 3].

The underlying theory of the absorption of the radiation energy by a sensor is a mechanical equivalent to 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 turn generated the output voltage and/or current of the sensors.

The Image Processing

Fig. 1 shows a block diagram of the overall main image processing system. Information content in an image can be enormous and various, depending on the subjects of interest. Searching for some specific information, the original image must be pre-processed, to enhance the visibility of the expected information. The end result is ready for display, storage, and/or transmission to other place [4].

Here, we attempt to utilize the image sensors which are able to capture the electromagnetic radiation in the infrared (IR) wavelengths. Proper enhancement and filtering processes should be looked into thoroughly on the data acquired by the RGB sensors of an ordinary digital camera. Figure 1 shows the main hardware blocks used.

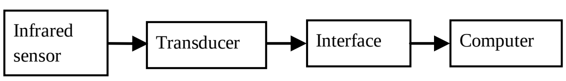

Figure 1: The four hardware blocks in our research.

Contrast Stretching

Point operations are zero memory operations where a given gray scale level $u \in [0, L]$ is mapped into a gray scale $v \in [0, L]$ according to a transformation $v = f(u)$ [5].

Low-contrast images occur often due to poor or non-uniform lighting conditions or due to nonlinearity or narrow dynamic range of the imaging censors. Figure 2 shows a typical contrast stretching transformation, which can be expressed as

$$y = \begin{cases} \alpha u, & 0 \le u < a \\ \beta u + (1 - \frac{1}{b-a})v_a, & a \le u < b \\ \gamma u + (1 - \frac{1}{L-b})L, & b \le u < L \end{cases} \quad (1)$$

where: $\alpha = \frac{V_a}{a}$, $\beta = \frac{V_b - V_a}{b-a}$ and

$$\gamma = \frac{L - V_b}{L - b}$$

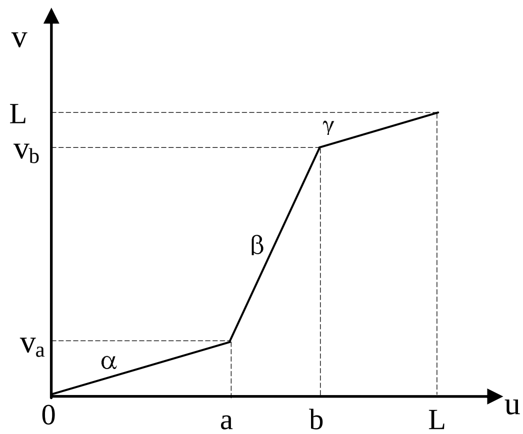

Figure 2: Contrast stretching transformation curve for intensity range between a and b [5].

The slope parameter β of the transformation is chosen greater than unity in the region of stretch, whilst α and β are less than 1. The parameters *a* and *b* can be obtained by examining the histogram of the image, where particular parts of interest in the image reside.

The Spatial Filter

Many image enhancement techniques are based on some spatial operations performed on local neighbourhood of every input pixel. In contrast with spectral filters, spatial ones involve much less computations in reducing the interfering noises and in bringing out the intended characteristics of certain objects in the image. Therefore the smoothing effect on the noises while minimizing the blurring effect on the objects of interest should be balanced resorting to the nature of the image. Noise reduction can be accomplished by blurring with linear filters as well as by nonlinear filters [5].

Spatial averaging (low-pass filtering)

The isolated pixels with gray values much different from its neighbors can be considered as impulses corresponding to high spatial frequencies. One way to get rid of this kind of noise is to use the average of a small local region in the image so that the out-of-range gray levels can be suppressed. Equivalently, this averaging operation in spatial domain corresponds to low-pass filtering in the spatial frequency domain.

The averaging operation is a weighted sum of the pixels in a small neighborhood and can be implemented by a common convolution with a kernel w of certain shapes and values:

$$\begin{aligned} y[m,n] &= \sum_{i,j\in w}\sum w[i,j]\,x[m-i,n-j] \\ &= \sum_{i,j\in w}\sum w[i,j]\,x[m+i,n+j] \end{aligned} \qquad (2)$$

where $w[i,j] = w[-i,-i]$ is a symmetric kernel of a limited size (typically 3x3, 5x5, 7x7, etc.).

Median Filter

Neighborhood averaging can suppress isolated out-of-range noise, but the side effect is that it also blurs sudden changes (corresponding to high spatial frequencies) such as sharp edges.

The *median filter* is an effective method that can suppress isolated noise without blurring sharp edges. Specifically, the median filter replaces a pixel by the median of all pixels in the neighborhood:

$$y[m,n] = median\,\{x[i,j],(i,j)\in w\} \qquad (3)$$

Where w represents a neighborhood centered around of the location (mm,n) in the image.

Moving Average

In statistics, a moving average, also called rolling average, rolling mean or running average, is a type of finite impulse response filter used to analyze a set of data points by creating a series of averages of different subsets of the full data set.

Given a series of numbers and a fixed subset size, the moving average can be obtained by first taking the average of the first subset. The fixed subset size is then shifted forward, creating a new subset of numbers, which is averaged. This process is repeated over the entire data series. The plot line connecting all the (fixed) averages is the moving average. Thus, a moving average is not a single number, but it is a set of numbers, each of which is the average of the corresponding subset of a larger set of data points. A moving average may also use unequal weights for each data value in the subset to emphasize particular values in the subset.

A moving average is commonly used with time series data to smooth out short-term fluctuations and highlight longer-term trends or cycles. The threshold between short-term and long-term depends on the application, and the parameters of the moving average will be set accordingly. Mathematically, a moving average is a type of convolution and so it is also similar to the low-pass filter used in signal processing. When used with non-time series data, a moving average simply acts as a generic smoothing operation without any specific connection to time, although typically some kind of ordering is implied.

C. Method of The Research

The experiment used consumer digital camera (Nikon D40X) and the thermal object is an electric iron.

D. The Result of The Research

The results of our experiments are shown in Figure 3(a) and (b), where the distinct object is an electric iron where the range of temperature around 90°C. The original image was obtained in “total darkness”.

(a) Grayscale.

(b) After stretching.

Figure 3: The acquired image.

Figure 3(a) shows the grayscale image acquired with IR filter which exhibits “total darkness”. Figure 3(b) after contrast stretching, shows clearly the surface of the electric iron and the granular noise.

(a) Lowpass

(b) Median

(c) Moving Average

Figure 4: Thermal image after filtering.

Figure 4(a) shows the result after the application of a 3×3 gaussian lowpass spatial filtering window, while Figure 4(b) shows the result with 3×3 median filter, and

Figure 4(c) shows the result with moving average method , where the latter is better in suppressing the granular noise and maintaining the bright object. A moving average compromises the noise suppressing effect and the blurring on the bright object. In this case, moving average method is better than filtering methods else.

E. Conclusion and Suggestion

1. Proper filtering method on thermal images obtained with a consumer digital camera can reveal better hot objects over their cooler background provided that the suited preceding filtering processes have been applied.

2. Further intensive experiments on thermal imaging practice are hopefully can expose the merits of the ever advancing consumer digital camera technology.

F. References

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