Surface (2D) Fitting to Exhibit the Inaccessible Isotherms Contours of Thermograms Acquired by Consumer Digital Camera

By s Sulistiyanti

Surface (2D) Fitting to Exhibit the Inaccessible Isotherms Contours of Thermograms Acquired by a Consumer Digital Camera

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Abstract

In this paper, we report our experimentation to enhance the visibility of hot object in a thermal image acquired with ordinary consumer digital camera, after the applications of contrast stretching. The moving average methods were used to suppress granular noises. Finally surface fitting and isotherm contours were made to estimate the fine temperature gradation of the thermal object.

Keywords

consumer digital camera, moving average method, surface fitting, isotherm contours.

I. Introduction

Ordinary 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.

Thermal images acquired with a modified ordinary digital camera bear granular noises due to the overstretching of the naturally very low intensity levels. Smoothing with moving average reduce significantly the visibility of these noises as well as the appearance of the hot object.

To expose better the thermal object of interest another nonlinear filters should be explored which do not demand complex or lengthy computations. For this, the merit of isotherm contours should be looked into experimentally.

II. The Underlying Theory

Today's digital cameras rely basically on their solid-state light sensors which generally sensitive to a wide range of 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, 4].

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.

A. 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 [5].

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.

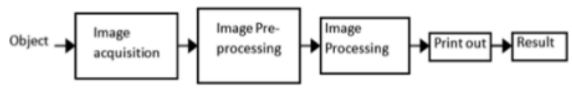

Image processing steps.

Fig. 1: The block diagram of a typical diagram

B. 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 $v = f(u)$ [1].

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. Fig. 2 shows a typical contrast stretching transformation, which can be expressed as

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

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

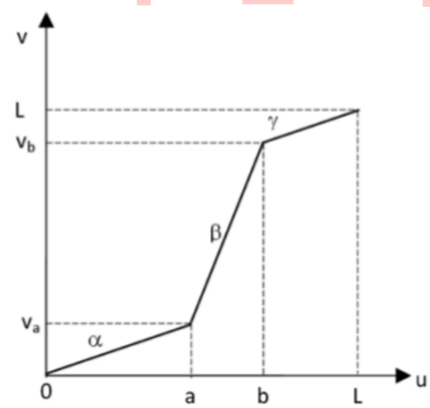

Fig. 2: Contrast stretching transformation curve for intensity range between a and b [1].

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.

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C. Surface fitting

Curve fitting is the process of constructing a curve, or mathematical function, that have the best fit to a series of data points, possibly subject to some constraints. Curve fitting can involve either interpolation, where an exact fit to the data is required, or smoothing, in which a smoothing function is constructed which approximately fits the data. A related topic is regression analysis, which focuses more on questions of statistical inference such as how much uncertainty is present in a curve that is fitted to data observed with random errors. Fitted curves can be used as an aid for data visualization, to infer values of a function where no data are available, and to summarize the relationships among two or more variables. Extrapolation refers to the use of a fitted curve beyond the range of the observed data, and is subject to a greater degree of uncertainty since it may reflect the method used to construct the curve as much as it reflects the observed data. Surface fitting is curve fitting for two dimensional data, such an image gray level variation.

III. Materials and Methods

The experiment used consumer digital camera (Nikon D40X) and Thermal Imager Ti20 (as a reference camera) where the thermal object is an electric iron.

IV. Results and Discussion

The images of an electric soldering iron are taken in "total darkness", where the pixel intensity levels fall below 20 in the range up to 255. Fig. 3 shows the resulting contrast stretched part of the image which shows the granular noises and rough contouring, where the parameters are a=37, $V_a = 7802$, b=97, and $V_b = 18899$ [3].

Fig. 3: After contrast-stretching.

Fig. 4 after surface fitting which shows clearly a continuous intensity gradation.

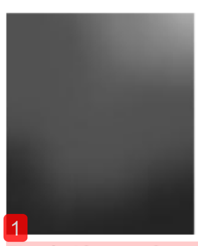
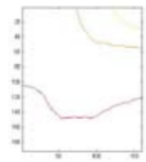
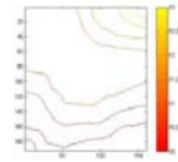


Fig. 4: After surface fitting.

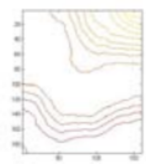
Fig. 6 shows another part of the thermal image showing the continuous temperature variations in black and white as well as in color after conformation with those obtained with Fluke Thermal Imager Ti20.



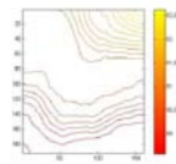
a) The smoother 3 contours that those in Fig. 3.



b) Eight contours.

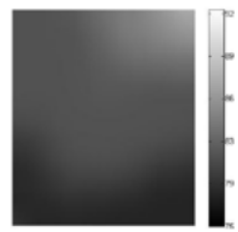


c) Thirteen contour.

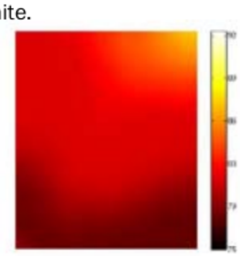


d) Seventeen contours.

Fig. 5: The color bar representation the smoothed intensity variation.



a) Black and white.



b) Hot level.

Fig. 6: The resulting continuous temperature variations gray level (a) and color variation (b).

V. Conclusions

A. Surface (2D) fitting can exhibit the isotherm contours of the thermal object which acquired by a consumer digital camera. Therefore, the nature of each thermal image should be understood properly, and the goal of this thermal imaging work is clearly defined.

B. Further and more extensive experiments with this low budget imaging practice can expose the merits of the ever improving quality of consumer digital camera technology.

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