International Journal of Electronic and Electrical Engineering.
ISSN 0974-2174, Volume 7, Number 3 (2014), pp. 281-286

http://www.irphouse.com

Temperature Estimation using Image Processing with Quantum Analysis

Rohit Rana and Harish Parthasarthy

Division of Electronics and Communication Netaji Subhas Institute of Technology, University of Delhi, New Delhi, India

Abstract

Temperature estimation is used in various field's of technology for acquiring data related to temperature and drive the application or process according to it. Today we have only few methods to determine temperature of the object or body, but all of them are not accurate. Therefore we need more precise methods of estimating and calculating the temperature. Through this paper we present a low error method in this paper better than the conventional methods of calculating temperature, which will not only reduce the error but will provide a right and concrete direction. We will take each object a blackbody radiating at some temperature and calculate that temperature by finding power spectrum.

Keywords: Tempearture estimation, quantum temperature, non-contact temperature measurement.

1. Introduction

Temperature measurement from digital image comes under the colorimetry branch of image processing, in which we deduce the temperature based on the color, intensity etc. When we acquire an image we either get color image or monochromatic image depending upon the instrument we are using.

A body radiates energy in the whole spectrum starting from low frequency of 10^2 Hz to 10^{24} Hz, but the energy radiated may vary from band to band. Therefore we don't get all these band's details in image from which we want to calculate temperature as energy radiated is directly proportional to temperature.

$$T_T \propto E_T \tag{1}$$

Where is the total temperature of the body and is the total energy radiated by body.

The signal received by three color sensors (RED, BLUE, and GREEN) can be written as

(2)

Where and is the spectral responsivity and spectral distribution.

To setup a system representing colors as linear combination of primary colors we make a set of spectral distributions which represents primary color set and can be written as

(3)

Where represents array and represents tristimulus values of primary colors in 3-D space.

Therefore now signal s can be represented as follows

With

Now the above 3-D signal is converted in the 2-D color plane or chromaticity diagram.

(4)

With

From above equation (4) we can find out the X, Y co-ordinates in chromaticity diagram or CIE and thus deduce the temperature.

Another method [2], suggest that instead of going with chromaticity diagram, just get temperature values using contact type sensors in different kinds of burners which generates different colors. Then put that data in MATLAB and do regression analysis and curve fitting to get intermediate colors values. The main techniques which [2] talks are following:

1. Analytic techniques
   a) Least squares method
   b) Polynomial method
2. Color segmentation approach
3. Regression analysis

Where is temperature,: , , are regression analysis coefficients: is Red, Blue, Green

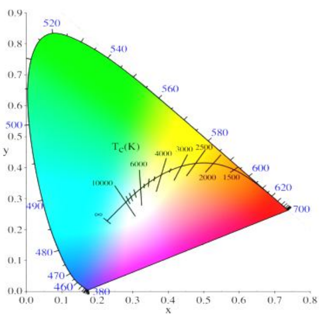

Fig. 1: Chromaticity diagram CIE[1]

2. Shortcoming of Chromaticity Diagram, Data Fitting and Regression Analysis

The main short coming was [1], [2] didn't consider the input properly which was frequency and wavelength dependent. They just considered the visible spectrum from electromagnetic spectrum. The main heat producing waves were in infrared region, cosmic and microwaves which contribute temperature of body a lot. For example if we take blue LED and a blue STAR, they can't have same temperature but we will get same temperature through above techniques.

Finally, we can say that we need a new solution to above mentioned problem which not only takes full spectrum inputs but can be used everywhere.

3. Temperature Estimation Using Image Processing with Quantum Analysis

We know a perfect blackbody radiates electromagnetic radiation at a constant temperature. According to Stefan-Boltzmann law, the power flux ϕ of a black body radiation at temperature T is

$$\phi = \sigma T^4 \tag{5}$$

Where σ is constant and the planckian spectrum $S(\nu, T)$ is given by

$$S(\nu, T) = \frac{8\pi h \frac{\nu^3}{c^3}}{e^{\frac{h\nu}{kT}} - 1} \tag{6}$$

where h=planck constant, ν=frequency, k=Boltzmann constant, T= Temperature

Now the power flux per unit frequency overall frequencies is given by

$$\int_0^\infty S(\nu, T) \tag{7}$$

Suppose the body radiates according to the planckian spectrum $S(\nu, T)$. Let $x(t)$ is the current induced in the photocell with zero mean and spectral density $\alpha S(\nu, T)$.The output of an LTI filter with impulse response $h(t)$ and additive noise $\omega(t)$ is

$$y(t) = h(t) * x(t) + \omega(t) \; t \geq 0 \tag{8}$$

Now $y(t)$ is a measured signal. It's a filtered and noise corrupted version, zero mean stationary Gaussian process with spectral density

$$S_y(\omega) = |H(\omega)|^2 \, S_p(\omega, T) + S_\omega(\omega) \tag{9}$$

where $S_p(\omega, T) = \hbar \frac{\frac{\omega^3}{\pi^2 c^2}}{e^{\frac{\hbar\omega}{kT}} - 1} \; \hbar = \frac{h}{2\pi}$

We can find estimate of T by $\hat{T}$, where $\hat{S}_y(\omega)$ is the estimate of $S_y(\omega)$ then it can be written as

$$\hat{T} = argmin \int_{T_0}^{\infty}(S_y(\omega) - |H(\omega)|^2 S_p(\omega, T) - S_\omega(\omega))^2 d\omega \qquad (10)$$

$\hat{T}$ is the temperature estimate based on least squares spectral matching. The maximum likelihood temperature estimator of T based on signal matching involve following:

1. find $S_{yy}(\omega) = |H(\omega)|^2 \, S_p(\omega, T) + S_{\omega\omega}(\omega)$
2. find $R_{yy}(\tau, T) = \int_{-\infty}^{+\infty} S_{yy}(\omega) e^{j\omega\tau} \frac{d\omega}{2\pi}$
3. find $Q(t_1, t_2) \; t_1, t_2 \in [0, T_0]$

T_0 is the duration of measurement of $y(\cdot)$

So that

$$\int_0^{T_0} Q(t_1, t_2) \, R_{yy}(t_2 - t_3, T) \mathrm{dt}_2 = \delta(t_1 - t_3) \; t_1, t_2 \in [0, T_0] \qquad (11)$$

We can write $Q(t_1, t_2 \colon T)$ instead of $Q(t_1, t_2)$ and now we minimize it

$$\zeta(T) = \frac{1}{2} \int Q(t_1, t_2 \colon T) \mathrm{y}(\mathrm{t}_1) \mathrm{y}(\mathrm{t}_2) \mathrm{dt}_1 \mathrm{dt}_2 + \frac{1}{2} \sum_{\mathrm{n}=1}^{\infty} \log \lambda_{\mathrm{n}}(\mathrm{T}) \qquad (12)$$

where $\{\lambda_n(T)\}_{n=1}^{\infty}$ are the eigen values of Q over $[0, T_0]$

Equivalently, let $\{\phi_n(t; T)\}_{n=1}^{\infty}$ and $\{\mu(t)\}_{n=1}^{\infty}$ the eigen functions (orthonormal set).

Now the associated eigen values of $R_{yy}(t_1 - t_2, T)$ over $[0, T_0]$ is given by

$$\int_0^{T_0} R_{yy}(t_1 - t_2, T) \phi_n(t; T) dt_2 = \mu_n(T) \phi_n(t_1; T), t_1 \in [0, T_0] \quad (13)$$

Then finally

$$\hat{T}_{ML} = argmin_T \left\{ \frac{1}{2} \sum_{n=1}^{\infty} \log\{\mu_n(T)\} + \frac{1}{2} \sum_{n=1}^{\infty} \frac{1}{\mu_n(T)} \left(\int_0^{T_0} \phi_n(t; T) y(t) dt \right)^2 \right\} \quad (14)$$

Thus we get the final equation through which we can find minimized error temperature estimate.

4. Results and Comparison

Following (III) method we are able to get very close temperature estimate of various radiating sources. It is shown in the Fig. (2).Also the sun planckian spectrum is shown in Fig. (2) after calculating the temperature from quantum model method compared with theoretical temperature of sun.

Table I

Image	Measured Temperature	Estimated Temperature	Error%
Sun	5771 K	5838 K	1.16
Candle flame	1900 K	1978 K	4.10
Florescent Lamp	2800 K	2896 K	3.42

Table (1) shows the comparison between the estimated temperature and theoretical or predicted temperatures. From it we can see the error is very low and we can apply this method on various objects.

5. Conclusion

In this paper we have shown a better method which take full radiated spectrum into consideration and produce result based on that. It works better than the conventional method and provides good insight of how things are working. This technique behaves well in matlab and it's easy to implement. Others methods can also be explored in this field.

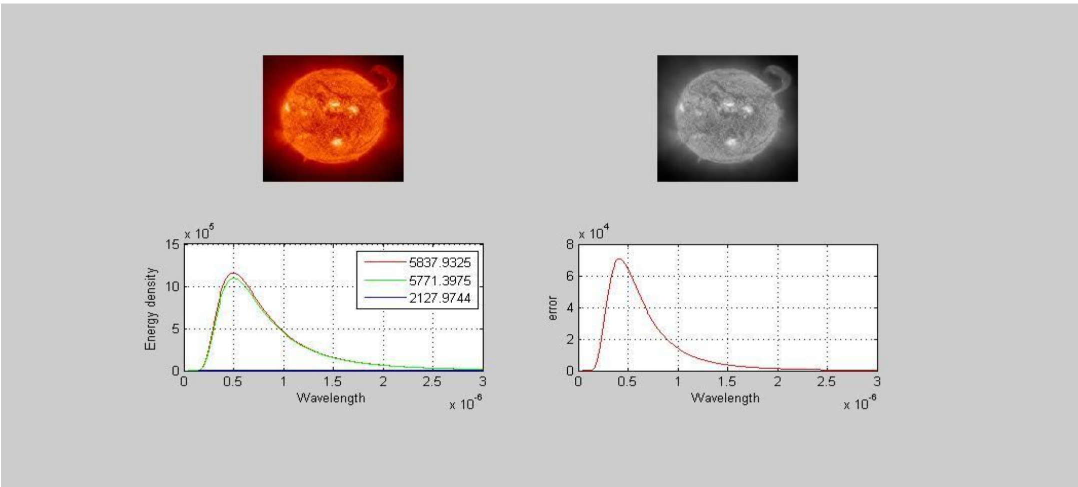

Fig. 2: Showing sun image in colored and lumen image, temperature and plackian spectrum of sun, error density in full electromagnetic spectrum.

References

[1] R. C. Gonzalez and R. E. Woods, *Digital Image Processing*, 2nd edition by Pearson Education Inc. 2002.

[2] Anagha M. Panditrao, Priti P. Rege, "*IEEE Trans. on instrumentation and measurement*, VOL. 59, NO. 5, MAY 2010.

[3] M. Abe and H. Ikeda, “A method to estimate correlated color temperatures of illuminants using a color video camera,” *IEEE Trans. Instrum. Meas.*, vol. 40, no. 1, pp. 28–33, Feb. 1991.

[4] P. M. Brisley, G. Lu, Y. Yan, and S. Cornwell, “Three-dimensional temperature measurement of combustion flames using a single monochromatic CCD camera,” *IEEE Trans. Instrum. Meas.*, vol. 54, no. 4, pp. 1417–1421, Aug. 2005.

[5] G. Lu and Y. Yan, “Temperature profiling of pulverized coal flames using multicolor pyrometric and digital imaging techniques,” *IEEE Trans. Instrum. Meas.*, vol. 55, no. 4, pp. 1303–1308, Aug. 2006.

[6] R. Rananath, W. Snyder, Y. Yoo, and M. Drew, “Color image processing pipeline,” *IEEE Signal Process. Mag.*, vol. 22, no. 1, pp. 34–43, Jan. 2005.

[7] K. Ito, H. Ihara, S. Tatsuta, and O. Fujita, “Quantitative characterization of flame color and its application: Introduction of CIE 1931 standard colorimetric system,” *JSME Int. J.*, vol. 35, no. 2, pp. 287–292, 1992.

[8] G. Lu, Y. Yan, G. Riley, and H. C. Bheemul, “Concurrent measurement of temperature and soot concentration of pulverized coal flames,” *IEEE Trans. Instrum. Meas.*, vol. 51, no. 5, pp. 990–995, Oct. 2004.

[9] M. Vrhel and H. J. Trussell, “Color image generation and display technologies,” *IEEE Signal Process. Mag.*, vol. 22, no. 1, pp. 23–33, Jan. 2005.

[10] A. Panditrao and P. Rege, “Estimation of the temperature of heat sources by digital photography and image processing,” in *Proc. IEEE I2MTC*, Singapore, May 2009, pp. 218–223.