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# Measurement of High Temperatures using Optical Pyrometry

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## Abstract:

Thermocouples are inefficient in measuring the temperature of the detonating carbon particles, whose temperature ranges from 1200K to over 1800K. An accurate and reliable method is required to measure such high temperatures of the carbon particles because temperature measurements will allow us to monitor and control the reaction kinetics of various industrially essential reactions. Optical pyrometry is thought to be one solution to this problem. It can be mono-color, two-color or multi-color. The two-color strategy is broadly utilized as a part of the non-contact temperature estimation of ignition blazes from radiation pictures, generally in view of the spectroscopic qualities of the picture sensor, and the delegate wavelengths for the red, green and blue channels of the picture shaping gadgets, for instance, Charge Coupled Device (CCD) cameras. In this research work, a strategy to get the temperature pictures from a digital advanced camera is delivered. The camera used for this work is Canon EOS750D Rebel T6i. In this strategy, it is important to catch picture data by the picture handling framework from a blackbody heater at various temperatures which cover the conceivable temperature scope of the ignition procedures to be estimated. The temperature measured by this method is validated in the literature. Modification in the existing method to make it more accurate is worthy of study.

***Keywords*** **— Temperature measurement, Coal particles, Optical pyrometry.**

## I. INTRODUCTION

Temperature is among the most regularly estimated amounts in burning coal examination.1 Various techniques for igniting carbon temperature estimations have been examined previously. At exhibit, the most broadly connected techniques utilize physical tests, for example, thermocouples or gas-examining tests, with clear impediments including meddlesome nature, debasement in unforgiving conditions, and single point estimation.2 As a broadly connected estimation strategy, the two-colour technique has been utilized for the temperature estimation of molecule loaded blazes. There has been a proceeding with exertion in applying this system to different circumstances.

This non-contact temperature estimation technique will profit numerous procedures where the contact of thermocouple is either not alluring (on the grounds that it might altogether change the temperature or different attributes of the subject), or isn't conceivable (on the grounds that the subject is moving, is too far away, is excessively hot or is in a generally antagonistic condition).

## II. THEORY

Most fast shading cameras comprise of a panchromatic CMOS imaging sensor that is delicate to light between 350– 1100 nm. This approaching "picture" hits the picture sensor chip, which splits it up into a great many pixels. The sensor measures the shading and splendor of every pixel and stores it as a number. Over the picture sensor is a Color Filter Array (CFA) that permits the generation of color pictures. The CFA is a mosaic course of action of colorful channels. Notwithstanding the CFA, most cameras have an IR cutoff channel to square radiation indistinct to the human visual framework.3 Camera frameworks are intended to reproduce a scene as observed by the human visual framework. Each shade or color based shading channel transmits a chose segment of the noticeable range to the pixel underneath it.

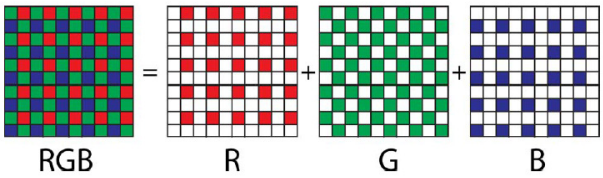


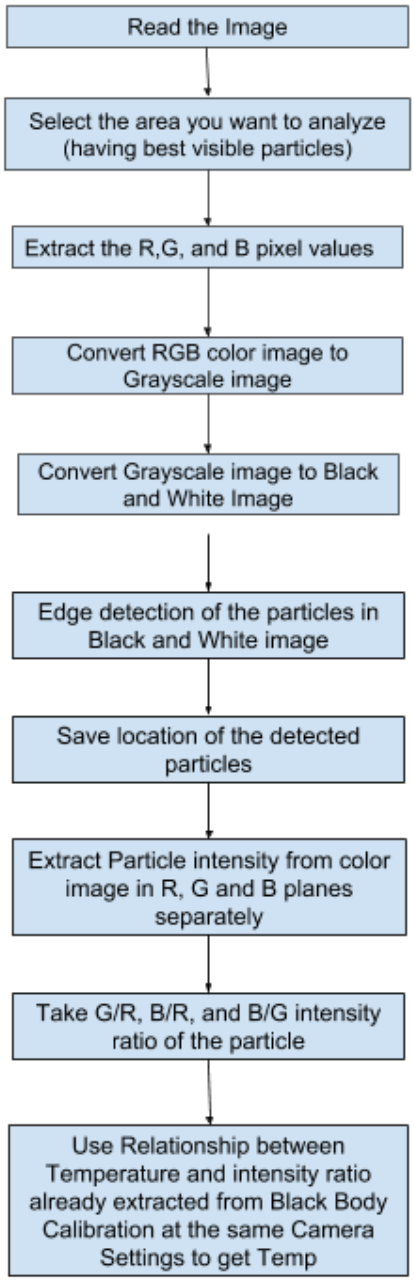

Fig: Representation of a CCD array that utilizes the Bayer Pattern

A full color picture comprises of pixels having three qualities that speak to the red, green, and blue shading channels. These three hues are consolidated to deliver a shading range. A demosaicing calculation is utilized to make a full shading picture from the CFA picture. Such a picture is a variety of square pixels masterminded in lines and segments, with every pixel demonstrating the power of light detected by the camera's identifier in the three-shading groups.

We can record the R,G,and B power esteems at each pixel. Intensity (I) alludes to the quantity of photons got by the camera, and in addition to the natural reflectivity or transmissivity of the object viewed. A pixel (short for picture element) is a little square that speaks to the measure of gray intensity to be shown for that specific bit of the picture. In a Grayscale picture, the pixel esteems are whole numbers that range from 0 (black) to 255 (white). Pixels in grayscale pictures require only one byte to show the power of dim expected to render the pixel on screen. For reasons unknown any shading can be constructed utilizing the right mix of red, green, and blue. Accordingly, pixels in shading pictures are spoken to by three qualities (r,g,b).

## III. EXPERIMENT AND METHODOLOGY

Black Body Calibration has been performed on the temperature range of 900°C to 1500°C. Images of the black body have been clicked (avoiding saturation of the pixel values) at a known temperature, this data has been used to produce a look-up table between Temperature and Intensity Ratio. MATLAB code is built to read the image and extract R, G, and B values to get the intensity ratios and hence the temperature. The Flowchart showing the algorithm of the code is as follows:



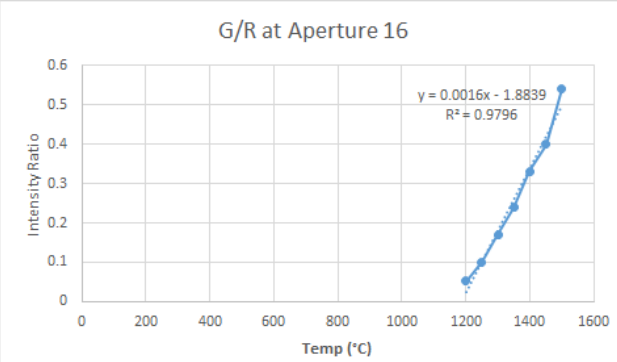

A method alternative to using MATLAB code is using ImageJ software to read the R, G, and B pixel values. Tecplot is used later to plot the Temperature values.

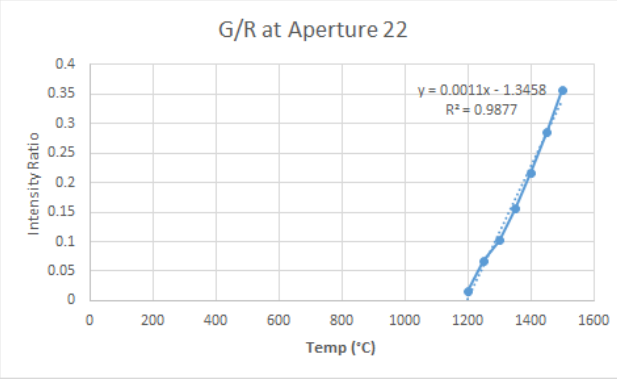
Note that the raw image has been used to process the intensity values because a camera's raw image file contains minimally processed data from the image sensor.

## IV. RESULTS AND DISCUSSION

Blackbody Calibration curves were obtained as follows: (At different Camera Apertures)

Note that Aperture 16 images has Saturation of the pixel values at above 1450°C while Aperture 22 does not have any saturation till 1500°C.




Following results were obtained while using our method and thermocouple to measure the temperature.

- Candle Flame:

B-type Thermocouple: (gave us the following values at different sections of the flame): 1261.70 ℃, 1370.46 ℃, 1208.23 ℃, 1172.43 ℃

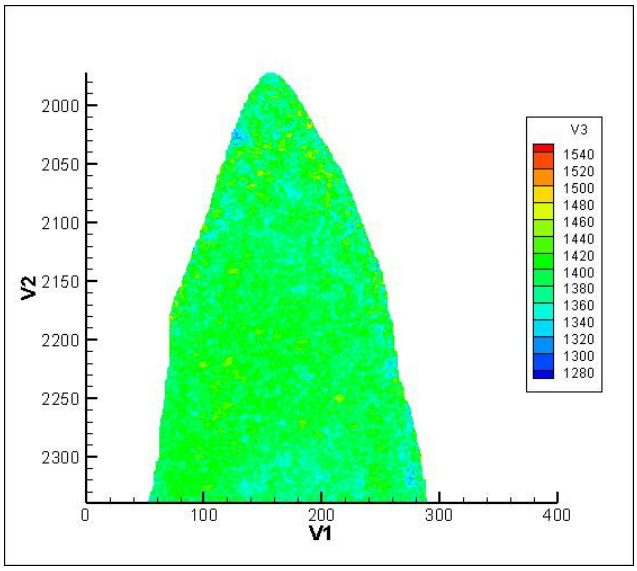
Our Method gave us the following values: (at Camera Settings: ISO = 200; Aperture = f/22; Shutter Speed = 1/4000 sec)

Average Temp Reading: 1285.601 ℃

Min Temp: 1158.667 ℃

Max Temp: 1371.167 ℃

Following Plot was obtained by measuring Temperature value at every pixel. (Tecplot was used to obtain this Temperature contour plot).




V1 = X coordinates

V2 = Y coordinates

V3 = Temperature values (in °C)

- Burner Flame:

(Thermocouple has been used to take the below readings)

Thermocouple Readings: 1419.79 ℃, 1424.43 ℃, 1478.45 ℃

Our Method gave us the following values: (at Camera Settings: ISO = 200; Aperture = f/22; Shutter Speed = 1/4000 sec)

Average Temp Reading: 1429.734 ℃

Min Temp: 1398.667 ℃

Max Temp: 1487.714 ℃

- Particles:

Thermocouple Readings: Not possible

Our Method: (Matlab code gives Temp readings for the particle very quickly and easily)

Camera Settings: ISO = 200; Shutter Speed = 1/4000 sec

| | With Quartz | Without Quartz |
|---|---|---|
| Aperture = f/22 | 1320.7□ | 1348.0□ |

| | | |
|---|---|---|
| Aperture = f/16 | 1375.7□ | 1396.7□ |

Note: The difference in Temperature readings is due to graybody assumption in our method. Having a correction factor (dependent on the ratio of spectral emissivities) will give correct temperature readings.

## V. CONCLUSIONS

A color camera pyrometer can be a helpful device for scientists in the ignition and energetics network. While at the same time the innovation does not take into consideration a totally tasteful gadget, appropriate arranging and configuration may give essential temperature estimations. To pick up the vital determination to gauge the temperatures not long after explosion, either a higher determination camera or zoom focal point ought to be utilized.3

Neutral density filters can be used to avoid the saturation of pixel values while taking pictures of the blackbody as well as the particles. Graybody assumption while measuring temperature can be looked into for temperature corrections based on the ratio of spectral emissivity.

## VI. FUTURE WORK

A multi-image lens which creates two parallel images on the same frame may be used to make the above method of measuring temperature more accurate. Narrowband filters may be used to allow specific wavelengths to pass through each side. Afterward, MATLAB code can be used to extract red signal intensity (for example) from one side and green signal intensity from the other side.

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