Non-Uniformity Correction and Replacement of Defective-Pixels on MWIR Images Using Black- Body Calibration

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ABSTRACT

To refine clearness of targets in the un illuminated region uses a simple technique called as Thermal Imaging with the help of Thermal Imager. But there is some noise exists on those thermal images termed as Fixed Pattern Noise (FPN), which is caused due to difference in Gain and Offset parameters of detectors used in Thermal Imagers. The Fixed Pattern Noise from the Thermal Images is removed by using a technique of Two-Point Non-Uniformity Correction (NUC). This technique consists of the detector response is measured by calibrating the Black-Body at two different temperatures by using a uniform illuminator. From that detector response, Gain and Offset values are calculated by using theoretical formulae. Later Plateau Histogram equalization is applied to improve contrast of the image. After Non-Uniformity correction, some pixels which are not corrected, considered as Defective Pixels. Defective Pixels are replaced by using a nearest neighbor algorithm, in which the Defective pixels are replaced with weighted average of its neighboring pixels. The simulation is carried out using Mat lab.

KEY WORDS: Non-Uniformity Correction, Gain Correction, Offset Correction, Plateau Histogram Equalization, Fixed Pattern Noise, Black body Calibration.

1. INTRODUCTION

To revamp the security in country's borders or in large industrial areas during blaze or gloominess uses a technique called Thermal Imaging. It is one of the night vision technology and it works in environment without any ambient light. In this method, images are formed from the heat instead of light by using a device called Thermal Camera. Thermal Imager (Thermal Camera) is originally a heat sensor which is used to capture heat from the objects and produce an electronic image by using that temperature differences in the wavelength of infrared radiation. The main concept of this paper is to eliminate Fixed Pattern Noise (FPN) from the thermal images, which is caused due to difference in gain and offset parameters of detectors used in thermal imagers that might be caused by differences in pixel size and variations in environment temperature. The Fixed Pattern Noise is eliminated through employing Non-Uniformity correction techniques. There are many techniques available under Non-Uniformity Correction. Those are classified as Single-point correction, Two-point correction, Multiple-point correction, and the improved Two-point correction. The most simplest and accurate technique is Two-point Non-Uniformity correction, which is used to remove Fixed Pattern Noise from the thermal images. This process is also implemented by calibrating the Black-Body at two distinct temperatures by using a uniform illuminator. The Black-Body produces electromagnetic radiation at constant, uniform temperature, termed as Black- Body emission. The emitted radiation detected by the detector, which works on the principle of photo voltaic effect. From the detector response, Gain and Offset values are calculated by using theoretical formulae. The detector response is assumed as a linear by multiplicative of Gain and additive offset. Later Histogram Equalization is applied to improve contrast of the image. One of the most important techniques is Plateau Histogram Equalization, which improves the contrast of an image based on algorithm.

After Non-Uniformity Correction, some pixels which are not corrected, those are termed as Defective-Pixels. Defective-Pixels are identified by comparing the pixel values in raw data with mean and standard deviation of raw data calculated at two different temperatures and replacement of Defective-Pixels by using a nearest neighbor algorithm, in which the Defective pixel is substituted with the weighted average of its neighboring pixels.

Related Works: Milton (1985), done a work on the quality of an infrared image using microbolometer array temperature. In this process, two techniques are implemented; those are stabilization of microbolometer array temperature by using a thermo electric cooler and updating correction coefficients from reference source. The outcome reveals that it compensates the influence of detector's temperature fluctuation and increase a time between shutter actuation processes.

Isoz (2005), performed a work on the calibration of sensor data by using one or more radiation sources at different radiance levels. The complexity of the radiometric calibration increases even more when a) the number of spectral bands to calibrate increases, b) the spectral range of the sensors to calibrate increases, c) the radiation level of the scene or object under interest (like hot spots) increases. If the accuracy in the calibration is to be maintained, all these factors will both increase the time needed to perform the calibration and the number and/or complexity of the radiation sources needed. The outcome reveals the data of sensor is collected in the 0.4 to 12μm region.

2. METHODOLOGY

Black-body emission: The amount of energy discharged from the Black-Body at constant, uniform temperature is called Black-Body emission. Black- Body is a physical body that assimilates all occurrence of no particulate radiation in the absence of rate of occurrence or direction of occurrence. Corresponding to Planck’s law, the emitted energy has a specific frequency response which is mainly based on heat of the body not on the shape of the body. The radiation of the Black-Body as shown in below graph.

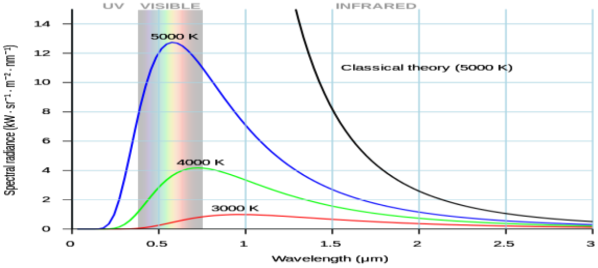

Figure.1. Black-Body Emission

The sweep is maximum at characteristic frequency that moves to exorbitant frequencies with growing heat, and at room temperature most of the emission is in the infrared range of the electromagnetic spectrum. The radiation represents a conversion of body’s heat energy into an electromagnetic energy called thermal radiation. From the graph, as the thermal reading of a Black-Body reduces, its intensity also reduces and its peak proceeds to over long wavelengths.

At constant room temperature, most of the energy emitted from the Black-Body is infrared radiation, and this radiation can’t be perceived by the human eye. As the temperature rises past over 500 °C, the Black-Body begins to propagate relevant quantity of perceptible light.

As growing heat of the Black-Body, the radiated heat becomes visible even when there is some backstage light, first it become visible as dull red, then yellow, and finally a “drazzling bluish-white” as the heat grows. When the body seems white, it is emitting a notable fraction of its energy as ultraviolet radiation.

Thermal Camera: Thermal Camera (Thermal Imager) is not a camera and it is indispensable a heat sensor which is used to collect the objects infrared radiation and shapes an electronic image depend on that information about the dissimilarities in temperature of the observed scene. Thermal Cameras are generally working in the far infrared range of the electromagnetic spectrum i.e., in the range of 9-14 µm. Thermal Cameras are almost identical to common camera that shapes a picture employ actinic radiation. In place of the 400-700 nanometer range of the actinic ray camera, invisible cameras operate in wavelengths being 14,000 nm (14 µm). When watched through a thermal imaging camera, warm objects protrude well opposed to cooler backgrounds. Humans and other warm-blooded animals get to be easily visible against the nature, day or night.

As a consequence thermography is outstandingly useful to the military and other users of surveillance cameras. Specialized invisible cameras using focal plane arrays (FPAs) those react to dragged-out wavelengths (mid- and long- wavelength infrared). Almost all regular varieties are InSb, InGaAs, HgCdTe and QWIP FPA. The advance guard use moderate, uncooled microbolometers as FPA sensors. Thermal imaging cameras are more exorbitant than seeable spectrum due to their structure of lens. The internal architecture of Thermal Camera as shown in figure below.

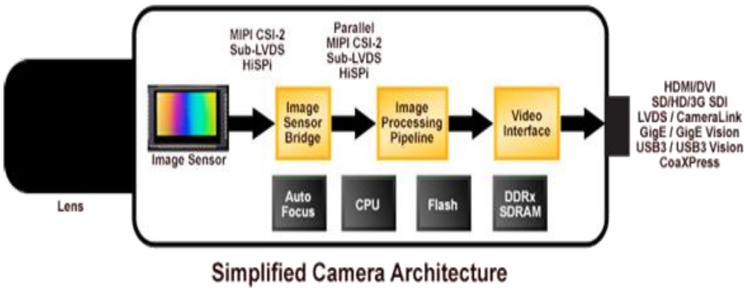

Figure.2. Internal Architecture of Thermal Camera

The Thermal Camera internally consists of

- Passive Infrared Sensor
- MWIR Detector
- FPGA Board
- FLASH Memory
- SRAM
- CCD Image Sensor
- LRF

Passive Infrared Sensor: This is an electronic sensor and it is used to measure heat emitting from targets. The term passive be relevant to the fact that passive infrared devices neither produce nor discharge any heat for detection purposes. PIR sensors do not recognize or determine heat instead they estimate the infrared radiation discharge or throw back from an object. All objects with a hotness beyond absolute zero emit heat energy in the appearance of radiation. Commonly this radiation is unseeable to the naked eye because it emits over infrared wavelengths.

MWIR Detector: A Medium Wave Infrared Detector employing at mid or long wavelengths to capture the heat emitted by an object. The Medium Wavelength Infrared (MWIR) and Long Wavelength Infrared (LWIR) bands acquire applications in Infrared Thermography for military or civil applications, e.g. target signature existence, surveillance, Non Destructive Evaluation. Most of the MWIR Cameras necessitate cooling, make use of either liquid nitrogen or a stirling cycle cooler, which is roughly -196ºC (77K).

FPAs are accessible in small, long, and very long format including 320x256, 640x512 and 1Kx1K pixel arrays. Indium antimonide photodiode detectors are photovoltaic, creating an electric current when it is experienced to Infrared Radiation.

FPGA Board: Virtex FPGAs are ordinarily programmed in hardware description languages like VHDL or Verilog, accessing the Xilinx ISE or Vivado Design Suite computer software.

A field-programmable gate array (FPGA) is an integrated circuit planned to be constructed by a customer or a designer after assembling – hence "field-programmable". The FPGA pattern is normally defined using a hardware description language (HDL), closes to that accessed for an application-specific integrated circuit (ASIC).

FLASH Memory: Flash memory is a memory bank which is effective for computers and electronics. It is most frequently accessed in tools like digital cameras, USB flash drives, and video games. It is entirely nearer to EEPROM. Flash memory is separate from Random Access Memory because RAM is not permanent. When power is shut down, RAM suffers the loss of all its data. Flash can retain its information unmarred with no power at all. A hard drive also is permanent (non-volatile) storage, but it is fundamental and hard.

Flash memory is moderate than RAM, but quicker than hard drives. It is abundantly accessed in small electronics because it is little and has no moving parts. Four Flash Memories are used in this process. Gain and offset values are stored in first two Flash Memories respectively. Locations of bad pixels are stored in third Flash Memory.

SRAM: Static Random-Access Memory (static RAM or SRAM) is a kind of semiconductor memory which requires bistable latching circuitry (flip-flop) to hoard each bit. SRAM shows data remanence, but it is still volatile in the prevailing sense that information is finally lost when the memory is not powered.

SRAM is quicker and costlier than DRAM; it is customarily used for CPU cache while DRAM is accessed for a computer's main memory. SRAM's are mainly used in calibration process for storing detector response at two different temperatures.

Non-Uniformity Correction: To eliminate Fixed Pattern Noise from the Thermal Images, Two-point Non-Uniformity Correction is applied on Thermal Images. The Non-Uniformity Correction process includes Gain Correction and Offset Correction. To achieve Non-Uniformity Correction, the response of sensor is acquired at two distinct temperatures through a uniform illuminator. To measure Raw data at high illumination is assumed as I1 and Raw data at low illumination is assumed as I2, and is averaged to reduce temporal noise. The detector response Di for the ith pixel in the linear array is given by

$D_i = q.C_i + p_i$ (1)

Where, GAIN p= median difference/pixel difference

Offset q_i= pixel from gain corrected frame-median of Gain corrected frame

C_i= IR radiation absorbed by the detector at i^{th} pixel

Final pixel value= original pixel value×Gain-Offset

After Non-Uniformity correction, the superior equation can be defined as

$C_i = q_i'. (D_i - p_i)$ (2)

Where, $q_i' = \frac{1}{q}$

Defining, $qi' = \frac{(J2 - J1)}{(J2i - J1i)}$,

$p_i = I1i$

I1i and I2i are ith pixel powers at lower and higher illumination respectively. I1 and I2 are the spatial averages of the image frames at lower and higher illuminations respectively and are defined as

$J1 = \frac{1}{M}\sum_{i=1}^{M} J1i$ (3)

$J2 = \frac{1}{M}\sum_{i=1}^{M} J2i$ (4)

Where M is the entire number of pixels in an array. Thus the precise output of the i^{th} pixel is given as

$C_i = \frac{(I2 - I1)}{(I2i - I1i)} * (D_i - p_i)$ (5)

The process of Non-Uniformity Correction includes Gain Correction and Offset Correction.

Gain Correction: To uniform the difference between Raw data those are calculated at two temperatures, Gain Correction is performed.

Table.1. Raw data at low illumination

10	10	15	14	12	

Table.2. Raw data at high illumination

20	15	30	28	24	

The first table represents the Raw data those pixel responses are calculated at low illumination. In the same way the second table represents the pixel response calculated at high illumination. The difference between pixel responses from two tables is not uniform. It varies based on response throughout the range. To uniform that difference, Gain Correction is performed.

First calculate the median of raw data1 at low illumination then calculate the median of Raw data2 at high illumination. Median value of Raw data1 is 12 and the median value of Raw data2 is 24 (From the values of table).

Then Gain = $median\ difference/pixel\ difference = (12-24)/(10-20) = 1.2$

In the same way calculate Gain value for each pixel. Those values are arranged in a table that is called as Gain table.

Table.3. Gain Table

1.2	2.4	0.8	0.85	1	

Table.4. Gain Corrected table1

12	24	12	12	12	…..

Table.5. Gain Corrected table2

24	36	24	24	24	…..

Now the pixel difference is uniform between two frames. Each frame consists of 512x640 elements.

Offset Correction: The detector response is not uniform at low illumination or high illumination. To get uniformity of the detector response, Offset Correction is performed. The Offset Correction is performed on Gain Corrected frame. The Offset value is calculated by using theoretical formula.

Table.6. Gain Corrected Frame

24	36	24	24	24	

Table.7. Offset

-12	0	-12	-12	-12	

Offset= Pixel from Gain Corrected Frame-median of the Gain Corrected Frame

The Offset values are arranged in 512x640 frame. Those values are shown in Offset table.

Final Pixel value= Original pixel value × Gain- Offset

Table.8. Final Pixel Values

36	36	36	36	36	

Now the response is uniform at any temperature. This is called as Offset Correction.

Plateau Histogram Equalization: To exceed the contrast of an image, apply a popular technique like Histogram Equalization. One simple and efficient algorithm based on plateau histogram equalization for the contrast enhancement of the infrared images. It preserves all the benefits of classical histogram equalization but does not extend the contrast of background enormously. By using this method, the image has been significantly enhanced without modifying the background information and thereby intensifies the brightness preservation. The proposed algorithm is applied on raw images, gain corrected images, and gain and offset corrected images and achieved satisfactory results.

Algorithm:

- Begin.
- Obtain Thermal Image by collecting heat from an object through the optical lens of a thermal imager.
- Consider the same image in matrix form which is having different pixel values.
- Arrange all the pixel values of the image in ascending scheme.
- Then generate histogram building.
- Calculate the Median for histogram data and finish-off to the closest integer value and defined it as threshold value.
- If the pixel means a given level k is more remarkable than the threshold value, then the pixel number is limited to the threshold value, for the most part of the pixel mean a given level k stays unchanged.
- Perform EXOR operation of corresponding two histogram values and say those values as Cumulative Distribution Function (CDF).
- Compute histogram equalization value for each pixel by using the formula:
  Histogram equalization= [(CDF value)/ entire number of pixels)]*[(Number of output precise)].

Bad Pixels: Bad Pixels are dead or defective pixels, those don’t have any useful information but they have more influence on nature of an image. So, Bad Pixels have to be detected and substituted by using a nearest neighbor algorithm. To identify bad pixels, we should follow a sequence of steps.

Those are;

- Rearrange the raw data in 512*640 matrix format.
- Calculate standard deviation in two dimensional by using std2 command.
- Calculate the mean value of raw data, which is calculated at 10^0C.
- Compare the pixel values in Raw data by using formula

(Mean-standard deviation) < (Raw data) > (mean+ standard deviation) then the raw data will be considered as good pixel or else it is considered as bad pixel.

The same process will be repeat for raw data calculated at 50^0C.

The Bad pixels are replaced with preceding value of the pixel but on one condition that preceding pixel must not be a bad pixel or else nearest neighbor algorithm, in which the bad pixel is substituted with weighted average of its neighboring pixels. This technique is implemented in Mat lab.

3. RESULTS AND DISCUSSION

Raw Data at High Illumination is measured are shown in Table 1 and corresponding Raw Data image is shown in Figure.3. In the same way Raw Data at Low Illumination is measured are shown in Table.2 and corresponding Raw Data image is shown in Figure.4. The Gain and Offset Data are shown in Figure.5 and 6 respectively. After applying Gain and Offset Data on capturing image through Thermal Camera is shown in Figure.7. Histogram Equalization is applied on Gain and Offset corrected image is shown in Figure.8. Defective pixels are identified by using theoretical formula is shown in Figure.9 and replacement of Defective pixel values with fair pixel values is shown in Figure.10.

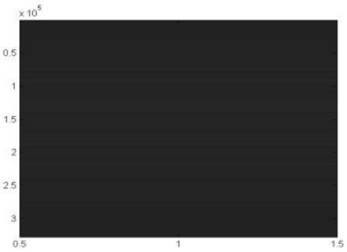

Figure.3. Raw data at low-temperature

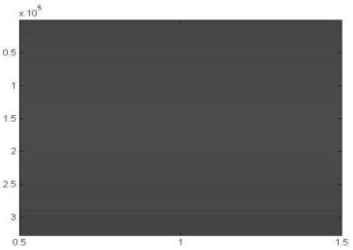

Figure.4. Raw data at high-temperature

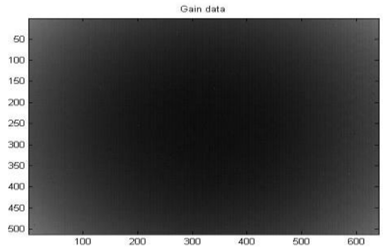

Figure.5. Gain Data

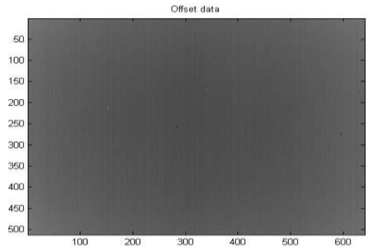

Figure.6. Offset Data

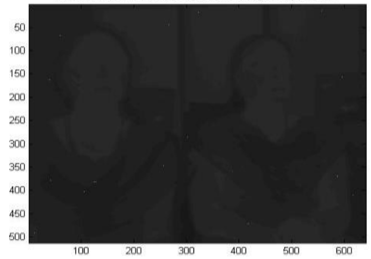

Figure.7. Gain and Offset corrected data without Histogram equalization

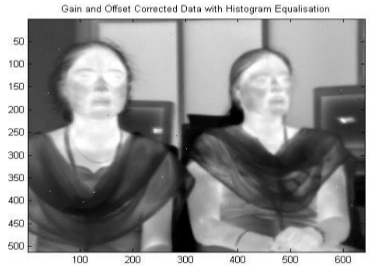

Figure.8. Gain and Offset corrected data with Histogram Equalization

Figure.9. Defective Pixels

Figure.10. Replacement of Defective Pixels

4. CONCLUSION

The Non-uniformity correction process is implemented in Matlab and results are shown in the significant reduction of fixed pattern noise compared to Single-point correction and Histogram equalization method improved the contrast of an image. The identification of Bad pixels and replacement of Bad pixels by using theoretical formulae is also implemented in Matlab and results showed the accurate image. This process is also performed on Xilinx platform.

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