# Algorithms and Hardware Implementation of Real Time Automatic Gain Control Feature for Thermal Imager


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## Abstract

*Thermal imagers operating in the 3-5 micron and 8-12 micron spectral bands require Automatic Gain Control (AGC) to enhance the visual detection and identification of targets against varying atmospheric conditions. In this paper, two algorithms viz., plateau equalization and adaptive plateau equalization algorithms are discussed for implementing AGC. The MATLAB simulation results show the effectiveness of these algorithms in controlling the levels of contrast. The plateau parameter selected for a scene renders targets easily recognizable and also provides contextual information about the surrounding regions. Results of the AGC algorithms on the IR images obtained by the 3-5 micron hand held thermal imager are discussed. The simulation results calls for hardware implementation using Xilinx SPARTAN-II FPGAs. The uniqueness of this paper lies in two features: one is the improvement suggested on the adaptive plateau equalization algorithm and the other is the hardware implementation approach.*


## 1. Introduction

Automatic Gain Control (AGC) techniques are of paramount interest in the Surveillance-Imaging system. In Hand–held Thermal Imager (HHTI), working in the 3-5 micron wavelength band, real-time contrast enhancement operation provides excellent images irrespective of day or night conditions. Scenes that are either predominantly dark or bright need to automatic gain control. Also, scenes with a dark foreground and a bright background are common. In this case, details in the foreground are limited to a few levels near the bottom of the dynamic range and objects in the background are crowded into a few levels near the top of dynamic range. By using auto-gain circuits, the contrast in the brightest portions of the scene can be improved, usually at the expense of the darker portions. Histogram equalization using plateau/adaptive plateau scheme has the ability to improve the contrast in all parts of the image by adjusting the gain in a nonlinear fashion optimally tailored for each input image [1].

The Automatic Gain Control (AGC) feature can be utilized in various classes of thermal imagers. The *uniqueness* of the paper lies in two features: one is the improvement suggested in the adaptive plateau algorithm and other one is the hardware implementation approach.

In this paper, the plateau and adaptive plateau equalization algorithm is discussed and the simulation results using Matlab on the images taken from HHTI camera have been shown. We found significant improvement in the image quality.

## 2. Contrast Enhancement Algorithms

Contrast enhancement is a pixel-point process involving the addition,subtraction,multiplication or division of a constant value to every pixel of an image. The plateau equalization and adaptive plateau equalization algorithms employed in our work of real-time incorporation of gain in the infrared images of Thermal Imager, also work on the basis of pixel point processing. On a pixel level basis, the gray level of each pixel in the input image is modified to a new value, often by a mathematical or logical relationship, and placed in the output image at the same spatial location. All pixels are handled individually. The general equation for a point process is given by the equation:

$$O(x, y) = m[I(x, y)]$$

where m is the mapping function.[2]

## 2.1. Plateau Equalization Algorithm

It is one of the most powerful contrast enhancement algorithm. The images are taken using HHTI based on a 320×256-element InSb Focal Plane Array detector. The histogram (number of pixels versus grayscale values) is calculated. To control the output image contrast, the histogram values forming the cumulative sum of pixels from the darkest intensity to the input intensity, are truncated to a specified constant "plateau" value. By removing the pixels above a certain "threshold or plateau" value in the histogram, the details of small objects against a wide background are preserved. If the plateau value is one, it is called histogram projection, which yields minimum contrast enhancement. While, if the plateau value is greater than or equal to the highest pixel count in any histogram bin, the algorithm reduces to histogram equalization & it provides maximum contrast.

Firstly, the histogram of grayscale value is generated. Then the cumulative addition of histogram bins is done from the darkest input intensity to the input intensity k:

$$g_k(P) = \sum_{i=0}^{k} r_i,$$

where $r_i$ is the minimum of the two values: plateau parameter or the count of pixels at that particular gray level.

Next, the new grayscale values are calculated as:

$$\omega_k = \{G * g_k(P)\} / g(P),$$

where G is maximum output value (for an 8-bit display, G=255) and g (P) is the total cumulative addition of all the pixels starting from k=0 to k=255. It forms an image using newly calculated grayscale values and thus incorporates contrast enhancement [3].

## 2.2. Adaptive Plateau Equalization Algorithm

Adaptive plateau equalization algorithm is an improvement over plateau equalization algorithm, in the sense that the plateau value is adaptively calculated for each scene. The basic idea behind this algorithm is to identify the "central" and "tail" regions of image histogram and find a plateau value, which ensures that each of these two regions occupies a specified portion of the output intensity range.The histogram made for any image has certain parameters which are used to calculate the plateau value adaptively. The figure 1 shows the sample histogram and its parameters :

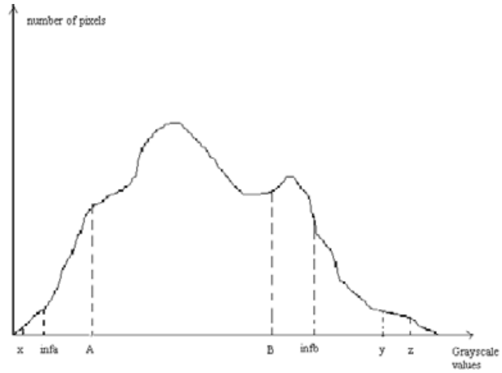


Figure 1: Histogram showing various parameters

The following parameters are calculated using the intensity histogram: -

*x*=Grayscale value where the number of pixels are 0.1% of total pixels,

*y*=Grayscale value where the number of pixels are 99.9% of total pixels,

*z*=Grayscale value where the number of pixels are 99.99% of total pixels,

*infa,infb*=Grayscale values at which the central region can be demarcated from lower end and higher end of histogram,

*A*=25% histogram intensity point,

*B*=75% histogram intensity point,

*Pixa*=Cumulative addition of pixels from gray scale 0 to grayscale infa,

*Pixb*=Cumulative addition of pixels from gray scale infb to grayscale 255,

*I (max)*=Grayscale value with maximum number of pixels,

*I (min )* =Grayscale value with minimum number of pixels,

The *infa* and *infb* points are found by applying a moving window sum of 3 consecutive histogram bins to suppress small bin-to-bin fluctuations. These points are calculated on the basis of change of the present moving window sum from the previous value by a threshold amount based on a fraction of the difference between the histogram minimum and maximum bin counts. The infa value should be less than *A* and *infb* should be greater than *B*. Also, the number of pixels at *infb* should be less than one-half the difference between maximum and minimum bin counts. The objective of this exercise is to calculate the plateau value (P) adaptively. For the histogram skewed towards the dark intensities: -

$$\mathrm{X} = \frac{\text{Number of pixels in central region}}{\text{Number of pixels in tails}}$$

$$= \frac{\mathrm{P} * (\inf b\text{-}\inf a)}{pixb + \mathrm{P} * (\inf a\text{ - }x)}$$

The value of X should be taken as 1 since it causes equal sharing of the output intensity range by the central portion and tails.

Solving for P: -

$$\mathrm{P} = \frac{(\mathrm{X} * pixb)}{(\inf b\text{-}\inf a)\text{ - }\mathrm{X} * (\inf a\text{-}x)},$$

when $(z - \inf b) > (\inf a\text{-}x)$ making a valid approximation that X*(*infa-x*) is negligible as compared to (*infb-infa*) so, for histogram skewed towards dark intensities: -

$$\mathrm{P_d} = \frac{(\mathrm{X} * pixb)}{(\inf b\text{-}\inf a)}, \text{when}$$

$$(z - \inf b) > (\inf a\text{-}x)$$

for histogram skewed towards bright intensities:

$$\mathrm{P_b} = \frac{(\mathrm{X} * pixa)}{(\inf b - \inf a)}, \text{when}$$

$$(z - \inf b) < (\inf a\text{-}x)$$

There is a dynamic range adjustment factor, which should be multiplied with plateau value, which is calculated as: -

$$\mathrm{F_{DR}} = 1 - (\frac{255}{R_\mathrm{D}}), \text{ Where}$$

$$R_D = (y - x) > 255$$

$$\mathrm{F_{DR}} = 1 - (\frac{R_D}{255}),$$

Where

$$R_D = (y - x) < 255$$

If the dark regions are quite extended, then an additional adjustment factor $F_{ED}$ is to be multiplied with the plateau value,

$$\mathrm{F_{ED}} = 1 - \frac{(A\text{-}x)}{(B\text{-}x)},$$

Finally, the resultant plateau value is: -

$$\mathrm{P_{res}} = P \times F_{DR} \times F_{ED}$$

After calculating the plateau value adaptively using this algorithm, the image is formed as illustrated in plateau algorithm [4].

An *improvement* is suggested in the plateau/ adaptive plateau equalization algorithm. As per Weber's law, the visual perceptible changes occur more in dark regions than in bright regions. So, in our algorithm, if the plateau value varies logarithmically over the grayscale value range of 0 to 255 as:

For index = 1 to 256

New plateau value=Plateau +log (x)

Consequently, more number of pixels will cut from dark regions as compared to bright regions and hence, a better contrast in the image could be obtained.

## 3. Simulation Results

The performance assessment of the two algorithms, viz. plateau and adaptive plateau equalization algorithm was done by collecting a set of infrared images. These images are obtained from 3-5 micron thermal imager. The scene contained varied contrast levels, and are collected under different environmental conditions. The results of improvement in images after incorporation of AGC algorithms along with their histograms are shown in figures 2-13. [5]

## 4. Hardware Implementation Approach

The architecture of this algorithm needs to be optimized for its real time implementation, as it is the requirement of the Thermal Imager. The software simulation of algorithms and improved image quality obtained after its implementation has encouraged us to do its hardware implementation in HHTI. Figure 14 shows a block diagram of the proposed VLSI architecture using a Xilinx Spartan-II XC2S200PQ208 FPGA [6].

The CCIR-B video signal from a 3-5 micron Thermal Imager is taken and digitized using an analog to digital convertor. The frame rate is 25 Hz. The pixel values of a frame are stored in SRAM. These pixel values are made input to a histogrammer, which generates the histogram. This raw data is fed to FPGA processing block, where it is processed using plateau/adaptive plateau equalization algorithms. The processed data is given to a Digital to Analog Converter (DAC) where it is converted to analog data. This analog output is mixed with the composite sync signal using an analog multiplexer. Then the output is displayed on a CRT monitor. The sync separator block is used to generate the horizontal, vertical and composite sync signals.

These sync signals are used to control the timing of the overall system . [7]

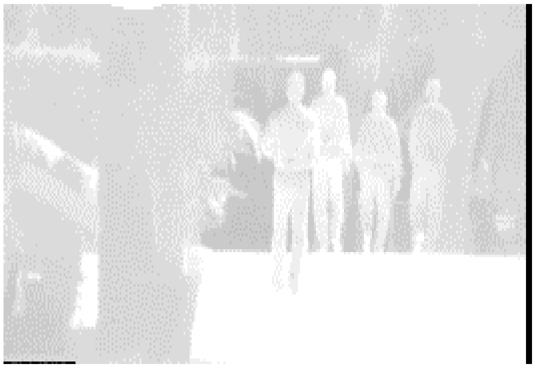

Figure 2: Input Image 1

Figure 3: Improved image 1 Plateau=194
Gain=1.4095

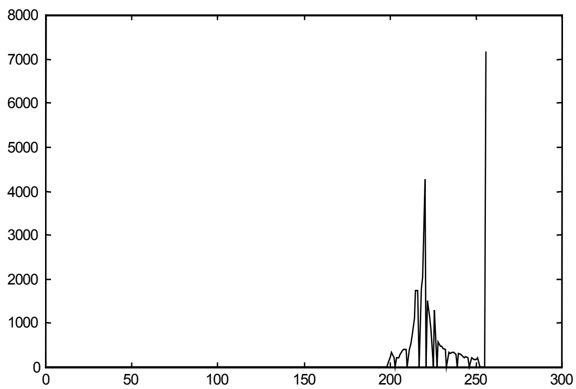


Figure 4: Input Histogram of fig.2

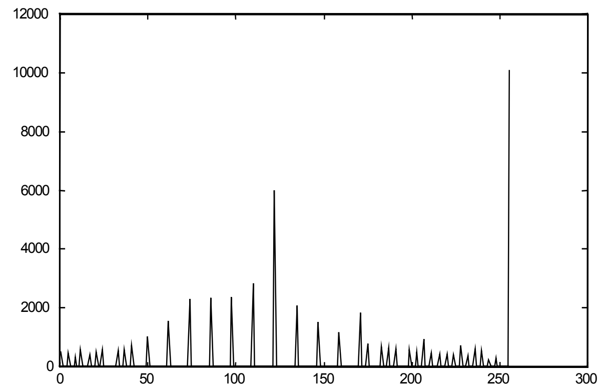


Figure 5: Output Histogram of fig. 3

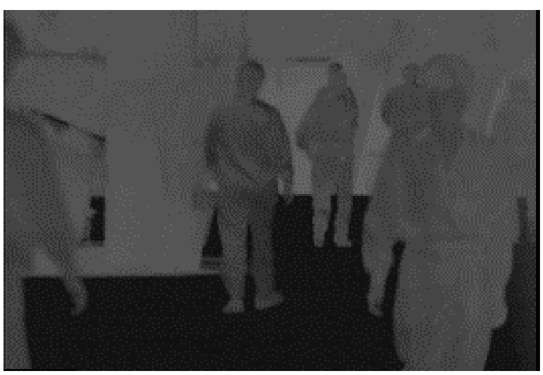

Figure 6: Input Image 2

Figure 7: Improved image 2 Plateau=18
Gain=0.0907

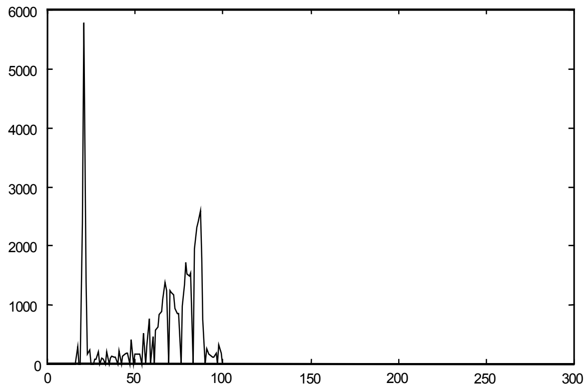


Figure 8: Input Histogram of fig. 6

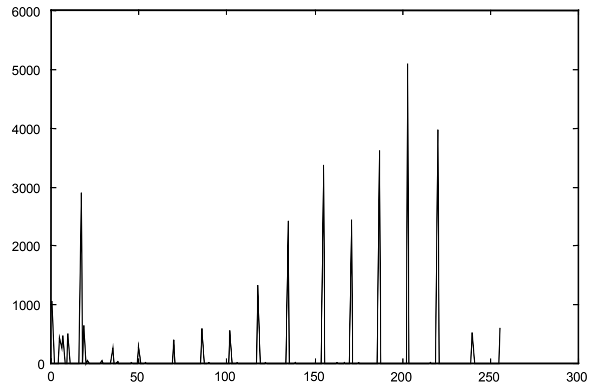


Figure 9: Output Histogram of fig. 7

Figure 10: Input Image 3

Figure 11: Improved Image 3 Plateau=365
Gain=1.4182

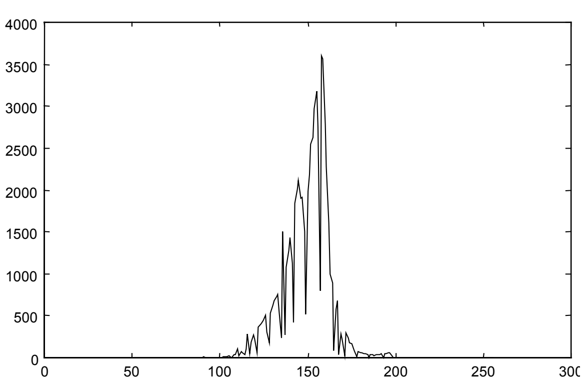


Figure 12: Input Histogram of fig. 10

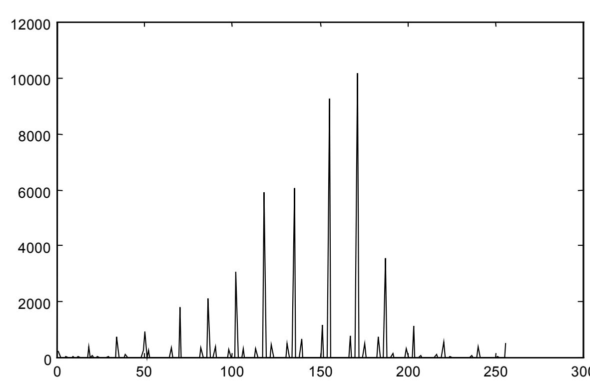


Figure 13: Output Histogram of fig. 11

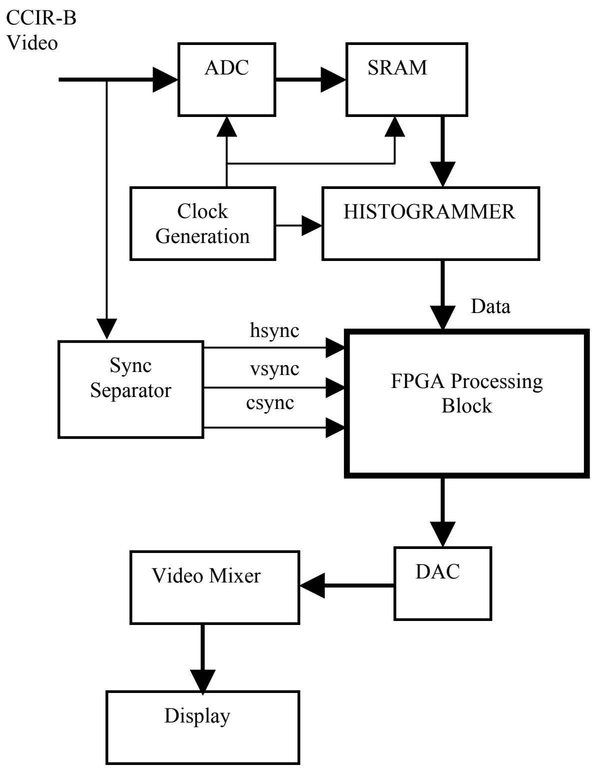


Figure 14: Hardware Implementation block diagram

## 5. Conclusions

The algorithms for Automatic Gain Control (AGC) of images provides for enhancement of background information while retaining target fidelity. The adaptive plateau algorithm automatically generates the optimal plateau parameter for input to a plateau equalization algorithm. Analysis and examination of histogram based plateau and adaptive plateau equalization algorithm on a wide variety of IR imagery calls for hardware implementation.

## 6. Acknowledgements

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## 7. References

1. N. J. McCaffrey, F. S. Pantuso, "Very Low Cost Histogram Based Contrast Enhancer Utilizing Fixed Point DSP Processing", Proc. SPIE 3303, PP 36-43.
2. W. K. Pratt, "Digital Image Processing", John Wiley & Sons, New York, 1978.
3.V.E. Vickers, "Plateau Equalization Algorithm for Real –Time Display of High Quality Infrared Imagery", Opt. Eng. 35(7), pp 1921-1926, 1996.
4. J. H. Gruben, Paul R. Neiswander, H.C. Tran, C. M. Webb, "Scene Based Algorithm for Improved FLIR Performance", Proc. SPIE 4030, pp 184-195, 2000.
5. MATLAB Users' Manual, Version 5, 1999.
6. Xilinx: The Programmable Logic Data Book, Xilinx Inc., San Jose, CA, 2nd Edition, 1994.
7. Analog Devices: Data Conversion Product Data Book, Analog Devices Inc., 1997.
8. J. Silverman, "Signal Processing Algorithms for Display and Enhancement of IR Images", SPIE Infrared Technology XIX, Proc SPIE 2020, pp 440-450, 1993.
9. Kevin Skahill, " VHDL for Programmable Logic", Addison Wesley, CA, 1996.