A research to the linear transform based on histogram statistic

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Abstract. The original image from infrared image system is low contrast and bad display. The parameters of typical linear transform arithmetic are achieved by experience. This paper proposes a new piecewise linear transform arithmetic based on histogram statistic and describes the architect of the hardware design to enhance image.

Introduction

The infrared image has some inherent disadvantage, such as low contrast between the target and environment, fuzzy margin, low SNR etc. This is owed to the inherent characteristic of the infrared detector in the infrared thermal imager, such as sensitivity, resolution ratio, noise. So the infrared image must be enhanced. In general, the enhancement arithmetic includes spatial domain method and frequency domain method[1,2]. Spatial domain method is direct pixel of image processing, for processing and spatial filtering two, processing methods including gray stretch, histogram processing, spatial filtering including median filtering, average filtering method[3,5].

Some enhancement arithmetic is complex. They need too many time and calculate resources. So they can be used to do MATLAB simulation on PC, not practical for actual design. The arithmetic by this paper implements a real-time piecewise linear transform, using less resource in FPGA.

The piecewise linear transformation based on histogram

The gray distribution of an infrared image is usually focused on its center with a cabined width, as Fig. 1 shows. If we expand its gray distribution to the full entire by some method, use all output gray level, the result image will be enhanced remarkable.

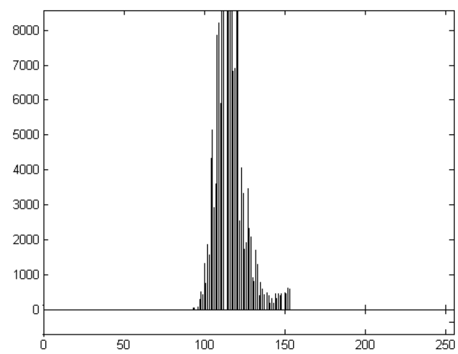

Fig. 1. Typical infrared image histogram

As Fig. 1 show, the effectual gray is centralized in a small range, only a little noise pixels have the gray exclude the range. The result is that images have bad display effect, low contrast. We can

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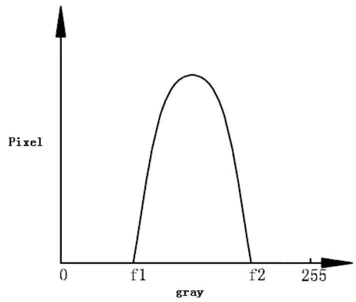
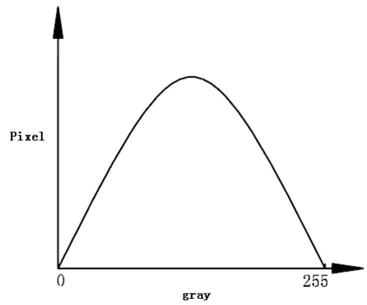
use Fig. 2(a) to predigest the histogram of infrared image. The gray centered on the pinnacle range while no or little gray exists exclude the range[6]. If we expand the pixels in [f1,f2] to [0,255], as Fig. 2(b) show, we can improve the contrast to enhance image. This method lost the information beyond the range [f1,f2]. To avoid this damage, we can execute a piecewise linear transformation, expand the gray [f1,f2] to [g1,g2], compress [0, f1] to [0,g1] and [f2,255] to [g2,255], as Fig. 3 and formula 1 show. Therefore, we can expand the target gray to enhance display effect while compress the background not noticed by people.



(a) initial histogram



(b) after linear transformation histogram

Fig. 2. The histogram of infrared image

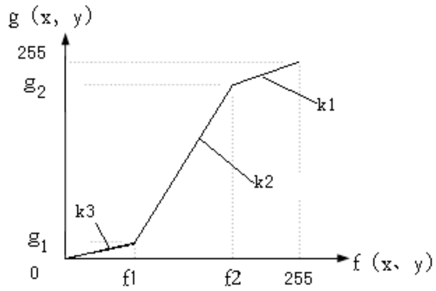


Fig. 3. piecewise linear transformation

In Fig.3,the mathematics formula[7] be described in formula 1:

$$g(x,y) = \begin{cases} k_1 f(x,y), & 0 < f(x,y) < f_1 \\ k_2(f(x,y) - f_1) + g_1, & f_1 < f(x,y) < f_2 \\ k_3(f(x,y) - f_2) + g_2, & f_2 < f(x,y) < 255 \end{cases} \quad (1)$$

Here,k1=g1/f1, k2=(g2-g1)/(f2-f1), k3=(255-g2)/(255-f2).

From formula 1, we can conclude that the pixels in range[0,g1] and [g2,255] are compressed, while pixels in range [g1,g2] are expanded, so the contrast is improved.

In practical engineering, with the target and environment moving, the main range [f1,f2] of infrared image is uncertain. If we want to implement the linear arithmetic, we must estimate the range [f1,f2] real-time with some method, then use this range to do linear transformation. For the noise pixel and bad pixel outside the main range, the estimation is difficult. If estimation is not appropriate, the result of the linear transformation cannot bate the environment, cannot enhance the target and depress the contrast. Fortunately, the pixels with gray outside the range are tiny, we use a histogram method to estimate the main range f1, f2. The method based on histogram is simple and easy to implement in hardware design. For an infrared image with pixels number S, summarize the pixels number with gray 0 to M, get the total numbers P1, then summarize the pixels number with gray 255 down to N, get the total numbers P2. Setting the P1 and P2 to proper number, we can use M and N to be f1, f2.

At first, we set g1 to 15, g2 to 240. These numerical values are derived from many experiments. Setting P1=P2=0.005S, P1=P2=0.001S, P1=P2=0.0001S, a initial infrared image is analyzed, shown in Fig.4 to Fig.7.

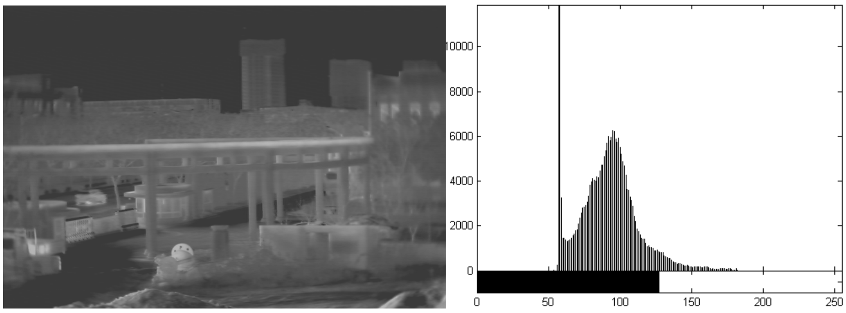


Fig. 4. initial infrared image and its histogram

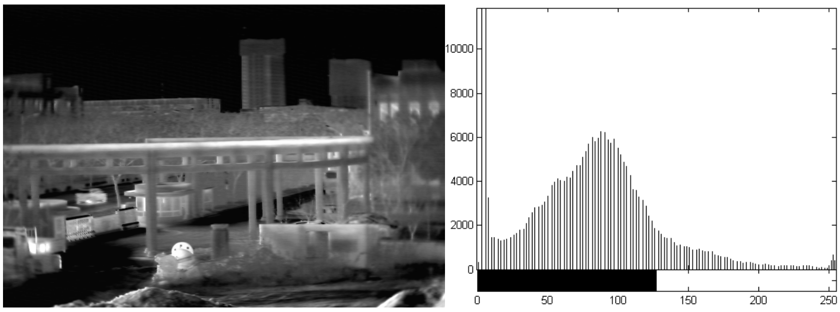


Fig. 5. after linear transformation(P1=P2=0.005S)

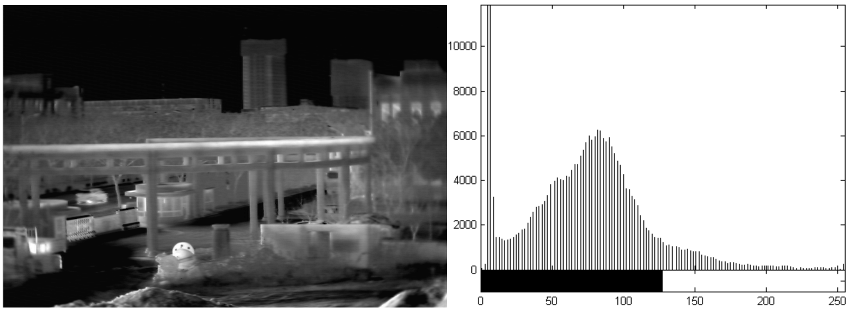


Fig. 6. after linear transformation(P1=P2=0.001S)

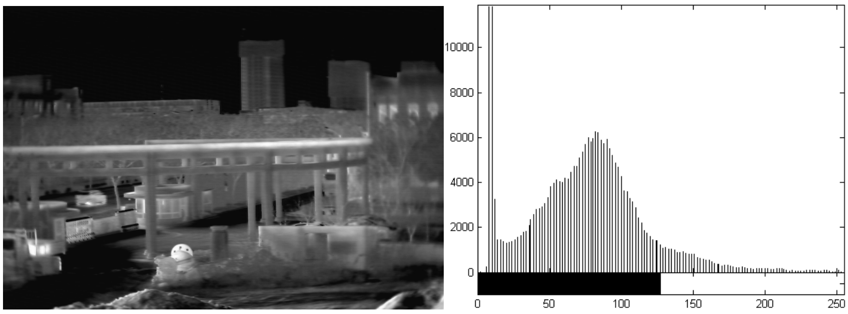


Fig. 7. after linear transformation(P1=P2=0.0001S)

As seen from Fig.6, the result image with P1=P2=0.001S is better than others.

The images in Fig.4 to Fig.7 show environment outdoor. Now we try to validate it at other conditions. In Fig.8 to Fig.9, we lay out images inside room. The effect of linear transformation is good and the enhancement to images is vast.

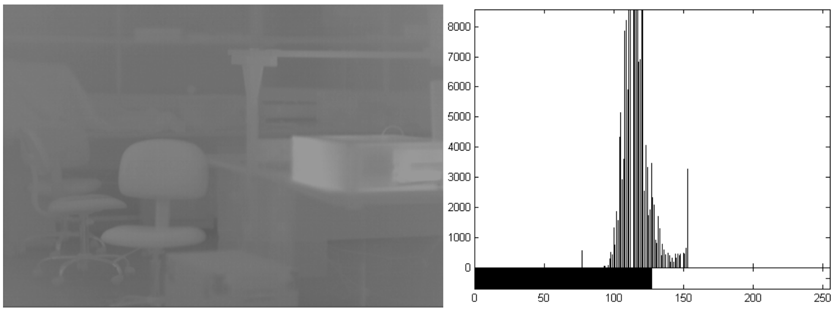


Fig. 8. initial infrared image in room and its histogram

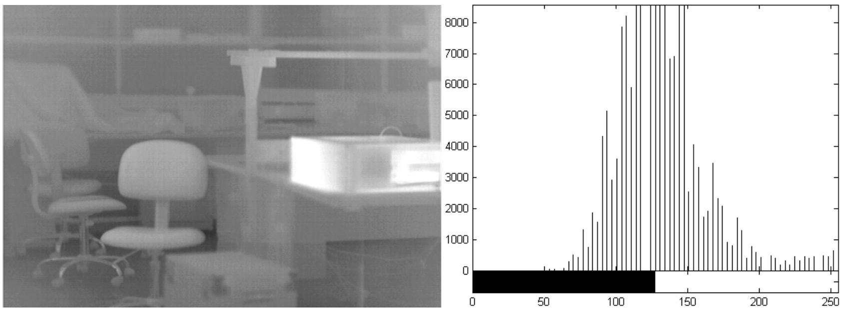


Fig. 9. after linear transformation(P1=P2=0.001S)

Hardware design to implement

We can use hardware to implement the piecewise linear transformation, as Fig. 10. shown. In this design, the module Ctrl is used to manage the work flow. When it received valid signal to be 1, that means the image is now receiving, it starts the linear transformation. The en signal is sent to min and max module to inform them to start working. At the same time, the address signal is counted and sent to SRAM module, making min and max module to read image data synchronously. After an image is read, the Ctrl module clear en signal, waiting for the ready signal, which indicate f1,f2 is generated. At last, en signal is set to make module draw to calculate the linear transformed data, using the formula (1). During the transformed image output, the Ctrl module generate indicate signal, sync to the status. After image output ok, the Ctrl module clear the en sent to module draw, and reply a finish signal.

In addition, the Ctrl module can receive instructions from keyboard or PC,modify P1 and P2,to improve the image in some especial environments.

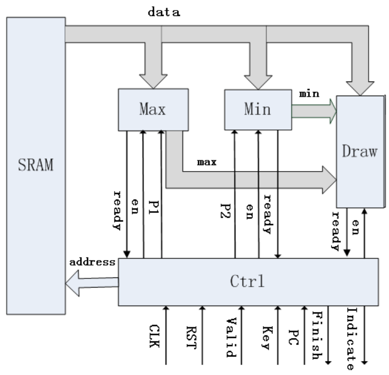


Fig. 10. Hardware structure diagram

Conclusions

After analysis to statistic of infrared images,this paper dispose a piecewise linear transformation arithmetic based the histogram,accomplish a hardware design using FPGA and achieve an excellent outcome. After experiments under variable environments,this arithmetic can get the proper f1,f2 parameters,making the output image to be enhanced perfect.

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