Improved Region of Interest for Infrared Images Using Rayleigh Contrast-Limited Adaptive Histogram Equalization

S. Erturk

Kocaeli University Laboratory of Image and Signal processing (KULIS)

41380 Kocaeli, TR

Abstract—**This paper presents an improved approach for region of interest (ROI) extraction in infrared (IR) images using Contrast-Limited Adaptive Histogram Equalization (CLAHE). Previous approaches use global image enhancement to increase the accuracy for ROI extraction in IR images. It is shown in this paper that the performance can be increased significantly using a local enhancement approach. CLAHE is used for this purpose in this paper to facilitate local image enhancement in an efficient way. It is shown that the proposed approach improves the ROI extraction performance.**

I. INTRODUCTION

Detection and tracking of targets in infrared (IR) images is an important task particularly for defence and security applications. However detecting targets in infrared images can be challenging because of changing environmental conditions, sensor noise and low signal-to-noise ratio imaging [1].

The region of interest (ROI) in the infrared image basically comprises image parts that potentially include any target of interest. In practice, the target of interest can be stationary or moving. In terms of application and utilization the ROI extraction process can be categorized into two approaches: human detected region of interest (hROI) which makes use of a human operator to identify ROIs, and algorithmically (or automatically) detected region of interest (aROI) which does not require user intervention and obtains the ROI automatically according to image characteristics through image processing [2]. This paper proposes a novel approach for the second case.

In case of video and moving targets it is possible to use optical flow [3], background difference [4,5] or frame difference for ROI extraction and potential target detection. However, these approaches are likely to fail in case of stationary targets. Furthermore in some applications it might not be possible to use a series of images from the same scenery, which might for example be the case if the infrared camera is mounted on a moving platform.

In cases of stationary targets or changing scenery, segmentation and threshold based approaches are typically in order to detect potential targets and extract ROI. In [6], the ROI extraction is accomplished using an intensity threshold that is adaptively obtained as

$$TH = \max\{I\} - \text{Intensity Margin} \tag{1}$$

where the intensity margin can be adjusted according to image characteristics to determine correct and false detection rates. In [7] it is noted that the ability of previous approaches to obtain an appropriate threshold value changes significantly across different scenes. Therefore an approach to consistently define a suitable threshold value has been developed in [7] and the ROI threshold is obtained as

$$TH = \arg\min_{\text{TH}}\{\sum_{i=1}^{TH} H(I_{ad}) \geq k \times A\} \tag{2}$$

where $H(I_{ad})$ shows the histogram of the smoothed intensity adjusted image, A is the total area of the histogram and k is a variable that can be used to adjust correct detection and false detection rates.

This paper proposes to improve the approach presented in [7] using a local enhancement approach. Contrast-Limited Adaptive Histogram Equalization (CLAHE) is utilized for this purpose in the threshold detection process. It is shown that the proposed approach significantly improves the ROI extraction performance.

II. Contrast-Limited Adaptive Histogram Equalization (CLAHE) of IR Images

Ordinary image histogram equalization (HE) uses the information derived from the entire (global) image histogram to transform all pixels of the image. HE is a successful enhancement approach if the distribution of pixel values is similar throughout the image. However, when the image contains regions that are significantly lighter or darker than most of the image, which is the typical case in IR images, the contrast in those regions is not sufficiently enhanced [8].

For infrared images that typically contain regions (typically targets) that are lighter than the overall image, local or adaptive histogram equalization (AHE) that uses local information to obtain a transformation function from the neighbourhood pixels is required for successful enhancement. The local neighbourhood used in AHE is usually referred to as image tile. Hence, AHE

operates on image parts (usually referred to as image tiles), rather than the entire image. For each pixel, a window around that pixel to cover the neighbourhood region, as shown in Fig.1, is utilized to obtain the transformation function of that pixel. In this way, the enhancement is performed in a local approach. This approach is applied to all pixels in the image. The transformation function is obtained just as in regular histogram equalization and the difference in AHE is only that a local image part is utilized in the enhancement process. The window size, or neighbourhood size, is a variable parameter that can be adopted according to image resolution, content and desired effect. To reduce computational load it is possible to divide the image into non-overlapping blocks (tiles) and apply AHE to each individual tile separately. In this case usually interpolation across block (tile) boundaries is utilized to avoid discontinuities.
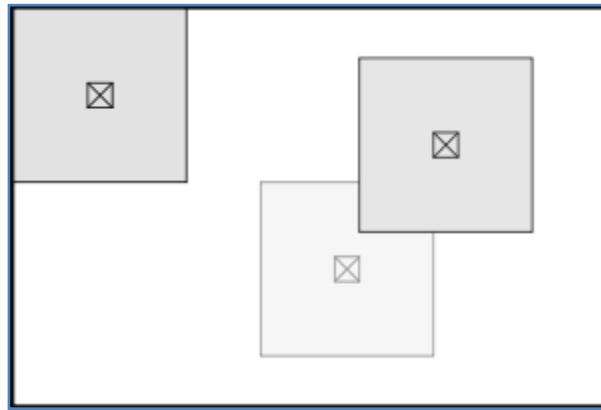

Fig.1. Neighbourhood window in AHE [12].

An important practical limitation of AHE is that image regions that are fairly homogenous can cause amplification of noise because in this case a narrow range of pixel values are mapped to the entire visualization range. Contrast limited AHE (CLAHE) was developed to prevent this over-amplification of noise in homogenous regions [9]. In histogram equalization the transformation function is obtained using the cumulative distribution function (CDF) of pixel values. The contrast amplification is given by the slope of the transformation function that is proportional to the slope of the CDF. CLAHE limits the amplification amount thereby avoiding undesired results in locally homogenous regions of the image. This is accomplished by clipping the histogram at a pre-defined fixed or adaptive value before computing the CDF to limit the slope of the CDF and hence limiting the slope of the transformation function. Uniform regions in an image tile will cause high peaks in the histogram in the corresponding pixel values. Originally, in CLAHE the part of the histogram that is above a certain level (clip limit) is redistributed among all histogram bins, as shown in Fig. 2, and because high values in the histogram are avoided through this approach, the slope of the CDF and in turn the slope of the transformation function will be limited.
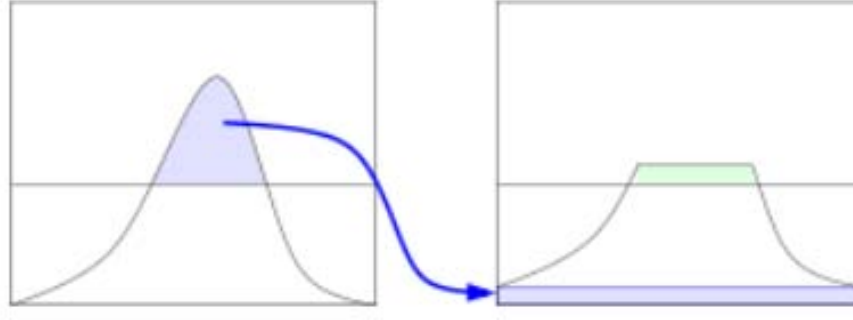
Fig2. Clipping of histogram in CLAHE [12].

In some applications, as in infrared imaging, a uniform re-distribution is not preferred because it distributes the corresponding values evenly into the entire dynamic range without discriminating between background and foreground and thereby also amplifies noise to some extent [10]. In order to overcome this problem it is possible to utilize non-uniform distribution functions. The Rayleigh function is one of the popular non-uniform distribution functions used for this purpose, enabling the image contrast to be enhanced without saturating uniform and high intensity areas [10] The Rayleigh distribution facilitates superior distribution of intensities so that good background and target (ROI) separation can be accomplished. Note that some other non-uniform distributions such as Gaussian and exponential are also available for this purpose.

Rayleigh contrast-limited adaptive histogram equalization (RCLAHE) can be divided into the following steps [10]:

Step 1: Divide image into tiles into non-overlapping regions (tiles)

Step 2: For each tile construct the histogram and clip the histogram by the input clip value.

Step 3: Transform intensity values after histogram clipping into the Rayleigh distribution. This can be defined mathematically in the form of

$$g = g_{min} + \left[2 \propto^2 \ln\left(\frac{1}{1-P(f)}\right)\right]^{1/2} \qquad (3)$$

where g_{min} is the minimum pixel values, $\propto$ is the Rayleigh distribution parameter, $P(f)$ shows the CDF and g is the computed pixel value. Note that a higher Rayleigh parameter ($\propto$) value results in increased contrast enhancement while increasing saturation and noise amplification.
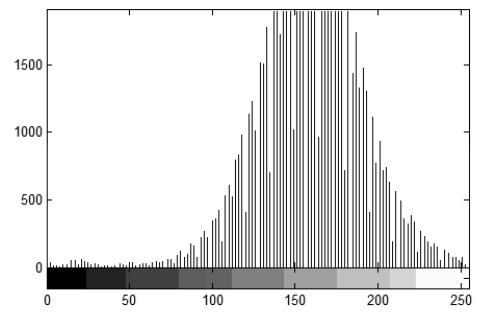
Step 4: Use interpolation (usually bilinear) of the mapping of each pixel of neighbouring tiles to avoid discontinuity.
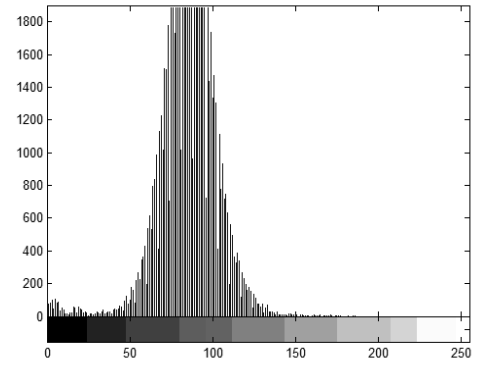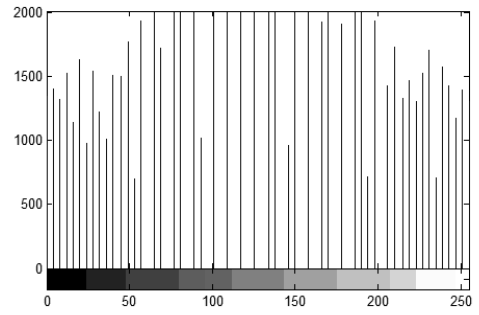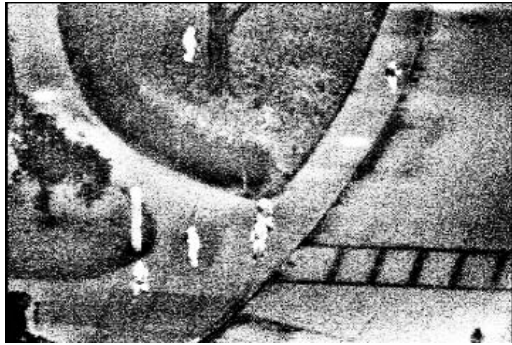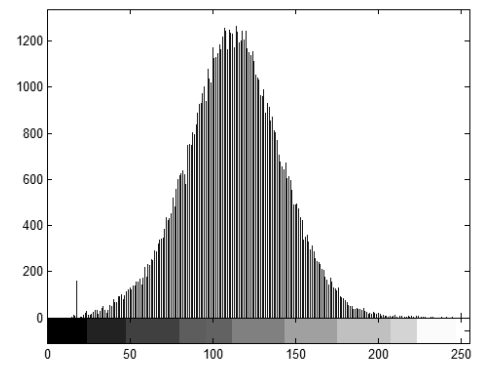
Fig. 3. (a) Sample IR image and histogram (b) Global HE result and histogram (c) Intensity adjusted result and histogram (d) RCLAHE result and histogram

Fig 3 shows a sample IR image together with the global HE result, the intensity adjusted result and the RCLAHE result together with the corresponding histograms. It is observed the RCLAHE provides superior enhancement in that the contrast in enhanced without over-saturation and over-amplification of noise.

In the proposed ROI extraction approach for infrared images the suitable threshold value of [7] has been adopted so that the ROI threshold is obtained as

$$TH = \arg\min_{\text{TH}} \{\sum_{i=1}^{TH} H(I_{RCLAHE}) \geq k \times A\} \tag{4}$$

where $H(I_{RCLAHE})$ shows the histogram of the Rayleight Contrast-Limited Adaptive Histogram Equalization Image, A is the total area of the histogram and k is a variable that can be used to adjust correct detection and false detection rates.

The utilization of RCLAHE as pre-process in the ROI extraction for infrared images enables superior performance by improving correct detection vs. false detection rates, as is shown in the experimental results section.

III. EXPERIMENTAL RESULTS

For comparison purposes the threshold detection approaches presented in [6] and [7] for ROI extraction in infrared images are utilized. To provide quantitative results, the OTCBVS Benchmark Dataset Collection [11] is used. Experimental results will be provided for Dataset 01: OSU Thermal Pedestrian Database, with 9 sequences (sequence 3 is excluded because it is in inverted form) having a total of 883 targets. Fig.4 shows the Receiver Operating Characteristic (ROC) curves for the approaches presented in [6] and [7]. The correct detection rate is the ratio of the number of correctly included targets in the ROI to the number of total targets present. The false detection rate is the ratio of the number of incorrectly included regions in the ROI (i.e. regions that are actually not targets) to the number of total targets present.
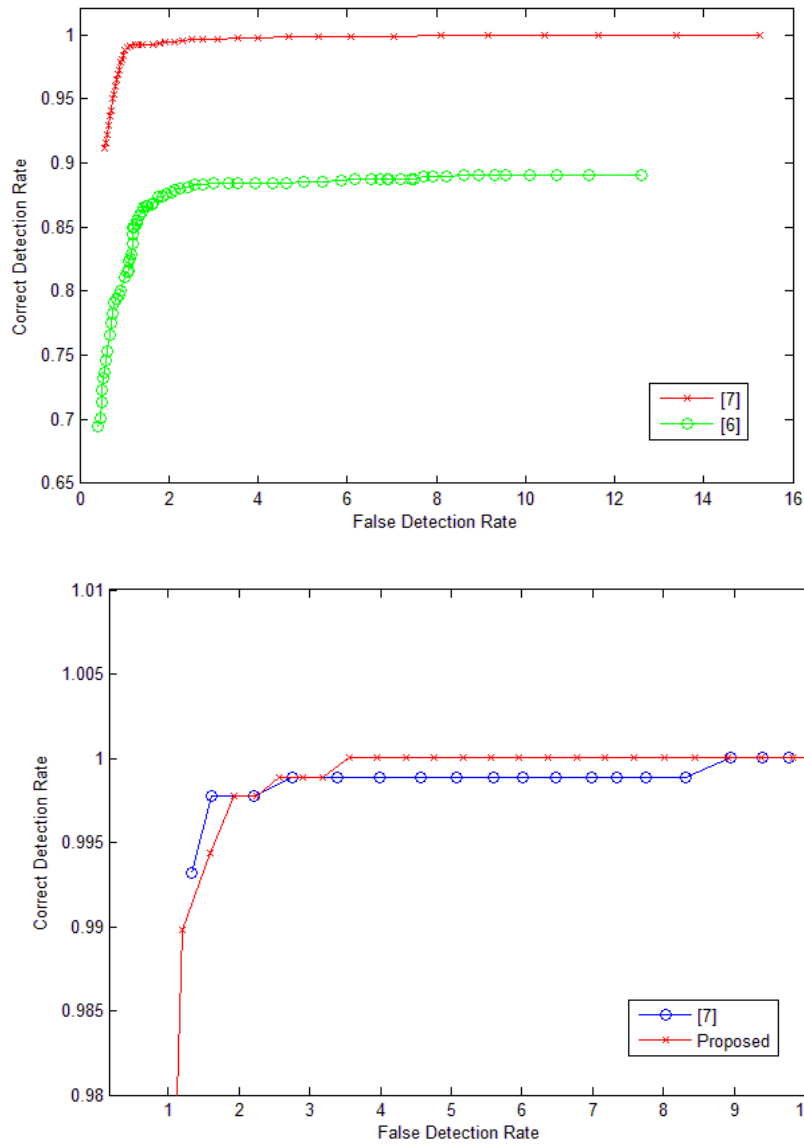
Fig 4. ROC curves for proposed approach, [6], and [7].

In the overall performance it is observed that the proposed approach as well as the method presented in [7] provides consistent threshold values for ROI extraction, which is not valid for the approach presented in [6]. An important point is the case in which all targets are correctly included in the ROI, i.e. the correct detection rate is unity. It is observed that the proposed approach provides lower false alarms in this case compared to the approach presented in [7]. For the 9 sequences used in the experimental results, in the case where all 883 targets are successfully included in the ROI extracted by the methods, the proposed approach provides only 3141 regions without target, while the approach presented in [7] provides 7901 regions without target. This is a significant reduction in ROIs that do not include any target, demonstrating that the proposed RCLAHE based approach provides superior performance.

IV. Conclusion

A novel approach for ROI extraction and potential target detection in IR images based RCLAHE is presented in this paper. Rayleigh Contrast Limited Adaptive Histogram Equalization is used to provide local enhancement of infrared images, improving the ROI detection accuracy. This information is used to obtain the final ROI of the infrared image. The process can be used as pre-processing in combination with other approaches to improve accuracy in future work.

Acknowledgment

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