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An X-ray Image Enhancement Algorithm for Dangerous Goods in Airport Security Inspection

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ABSTRACT

Aiming at the problem of color distortion in CLAHE enhanced airport security X-ray images, an X-ray image enhancement algorithm combining USM+CLAHE is proposed. First, calculate the grayscale images on the R, G, and B channels of the X-ray image and perform CLAHE enhancement respectively, and then merge the enhanced R, G, and B grayscale images. Next, perform the USM sharpening operation on the X-ray image enhanced by CLAHE, and finally merge the original image and the USM sharpened image according to the weight. The experimental results show that the USM+CLAHE algorithm can effectively enhance the security X-ray image, and at the same time can suppress the color distortion of the enhanced image.

KEYWORDS: Airport Security, X-ray Image, USM, CLAHE, Image Enhancement

1. INTRODUCTION

Because X-ray technology has the advantages of small damage to items, no need to open the box, safety, reliability, and easy operation, it is widely used in airport passenger security inspections and other occasions. Items of different materials have different degrees of X-ray absorption and scattering attenuation, and the corresponding X-ray images generated by items have different colors. Combined with morphological features such as edges and shapes, security personnel can identify prohibited items carried in luggage and packages, such as controlled knives and guns. Flammable and explosive materials, etc. Due to the various types of checked items in luggage and parcels, they are prone to overlap, block, and mix. In addition, items are easily affected by various interference factors in the process of forming X-ray images, and the collected security X-ray images may exist Items are blurred, low contrast, background noise, etc. In order to facilitate the security personnel to identify the items in the X-ray image, it is necessary to enhance the security X-ray image to highlight the color, edge, shape and other details of the different items in the image, so that the security personnel can identify the inspected items more accurately and quickly, to ensure the safe operation of the airport.

At present, domestic and foreign research related to X-ray image enhancement is mainly concentrated in the medical field and industrial inspection field [1–5], and there are few literatures on X-ray image enhancement in security inspection [6–8]. Histogram equalization (HE) is the most commonly used image enhancement method, which has the characteristics of simple principle, easy implementation, and good real-time performance. Contrast Limited Adaptive Histogram Equalization (CLAHE) is a local histogram equalization enhancement algorithm, which is based on the local adaptive histogram enhancement algorithm (Adaptive Histogram Equalization, AHE), and uses a fixed threshold the limiting method effectively suppresses the excessive enhancement of local contrast and the amplification of noise, especially suitable for low-contrast images. The CLAHE algorithm combines the advantages of two technologies, adaptive histogram equalization and limited contrast, and has received extensive attention from researchers. Sun Dongmei et al. [9] introduced an adaptive parameter T to automatically adjust the pixel redistribution range of each sub-block of the image, so as to achieve the purpose of enhancing image details. Wang Hong et al. [10] used the fuzzy enhancement algorithm to achieve the adaptive contrast enhancement of the global foggy image, and then used the constrained local histogram algorithm to process the brightness component of the foggy image to improve the brightness and contrast of the foggy image. Yang Weizhong [11] used the CLAHE algorithm to enhance the underwater sea cucumber image, which effectively kept the sea cucumber image details and improved the image quality. Liu Yuting et al. [12] combined CLAHE algorithm and bilateral filtering algorithm to effectively enhance the contrast and edge detail information of the original infrared image.

Aiming at the characteristics of X-ray security images, this paper proposes an X-ray security image enhancement algorithm based on USM+CLAHE. First, CLAHE is used to enhance X-ray images. Then the enhanced X-ray image is subjected to USM sharpening processing to further highlight image details. Finally, the sharpened image is merged with the original image to reduce the color distortion of the enhanced image, making it easier for security personnel to identify the items in the image. Experimental results show that the method security inspection images, and can effectively improve image clarity.

2. X-Ray Security Inspection Image Enhancement Algorithm Algorithm Based on USM+CLAHE

This section will elaborate on the security inspection X- ray image enhancement algorithm process: (1) CLAHE enhancement. First, calculate the grayscale images on the R, G, and B channels of the X-ray image and perform CLAHE enhancement respectively, and then merge the enhanced R, G, and B grayscale images. (2) USM sharpening. This algorithm uses an improved USM (Unsharp Mask) algorithm to sharpen the CLAHE-enhanced image to highlight details such as image edges and shapes. The USM algorithm combines the sharpened image with the original image according to the superposition coefficient for the second- level image fusion. (3) Image fusion. The original image and the USM sharpened image are weighted and summed to reduce image color distortion.

A. CLAHE Enhancement

The image histogram, also known as the gray level histogram, is used to represent the statistical relationship between each gray level in the image I(x,y) and the frequency of the gray level. The definition of the histogram is shown below.

$$P(rk) = \frac{n_k}{N}; \quad (1)$$

Where (k=0,1,2,..,L-1)

Among them, where n_k is the number of pixels of the k-th grayscale, N is the total number of pixels in the image, is the k-th grayscale, L is the number of grayscales, and $P(r_k)$ is the image I(x,y). The probability that r_k gray level appears.

Histogram equalization (HE) is a method of automatically adjusting image contrast quality using grayscale transformation. The basic idea is to stretch the grayscale histogram of the original image from a relatively concentrated grayscale interval to the entire grayscale range. The uniform distribution. Adaptive Histogram Equalization (AHE) is different from the ordinary HE method. The AHE algorithm changes the image contrast by calculating the local histogram of the image, and then redistributing the brightness, which can effectively improve the local contrast of the image and obtain more image details. But AHE has the problem of excessively amplifying the noise in the image.

- Image sub-region division: The original image is divided into multiple sub-regions of equal size, each sub- region does not overlap each other and is continuous with each other, and the number of pixels contained in each sub- region is C. The larger the sub-area, the better the enhancement effect, which can usually be adjusted according to actual needs.

- Calculate the histogram: Use $H_{ij}(k)$ to represent the histogram of a certain subregion, k represents the gray level and its value is [0, L-1] and L is the number of gray levels.
- Calculation limit value: Calculate the cutoff limit value is showed.
- Among them, βis the calculated limit value; α is the cutoff coefficient, and its value range is [0,100]; S_{max} is the maximum slope, used to determine the contrast enhancement amplitude, and its value is an integer between 1 and 4.
- Redistribute pixels: For each sub-region, use the corresponding β value to crop $H_{ij}(k)$ and redistribute the cropped pixels to the gray levels of the histogram. The above allocation process is performed cyclically until all the cropped pixels are allocated.
- Histogram equalization: Perform histogram equalization on the gray histogram of each sub-region after cropping.
- Reconstructed pixel gray value: use the center point of each sub-region as a reference point to obtain its gray value and use bilinear interpolation to perform gray linear interpolation on each pixel in the image to calculate each pixel in the output image the gray value of the point.

B. *Image Merge*

In order to improve the color fidelity of the processed image, the grayscale images on the three channels of the original image R, G, and B are calculated and CLAHE enhancement is performed respectively, and then the enhanced R, G, and B grayscale images are combined and converted into RGB, HSV image, and then CLAHE enhancement of RGB image and HSV image respectively, the enhanced image is respectively marked as I_r, I_q, I_b. Merging to achieve the first level of image fusion, the merged image will undergo USM sharpening processing

$$I_{merge}(i,j) = \sqrt{I_r^2(i,j) + I_g^2(i,j) + I_b^2(i,j)}; \quad (5)$$

Where (i=0,1,2,...,M-1 ; j=0,1,2,...,N-1)

Among them, I_{merge} is the merged image; M and N are the number of rows and columns of the image, the same below.

C. *USM Sharpening*

In order to facilitate the security personnel to observe and recognize the shape of the object in the X-ray image, it is necessary to use image sharpening technology to highlight the fine sections of the image, especially the edge information of the image. Image sharpening is an image processing method to make the edges of the image clearer. The principle is to first extract the high frequency components of the original image, and then superimpose it with the original image according to certain rules, and finally get the sharpened image. The traditional unsharp mask (USM) operation can remove some small interference details in the image, but the resulting sharpened image is prone to noise and false edges. Therefore, this paper adopts the USM algorithm combined with threshold. The main steps are as follows.

- Gaussian filtering the original image I to get the filtered image I_{blur}.
- As shown, calculating the mask.

$$Mask(i,j) = \begin{cases} 1, & if\ |I(i,j) - I_{blur}(i,j)| \le Threshold \\ 0, & if\ |I(i,j) - I_{blur}(i,j)| > Threshold \end{cases} \quad (6)$$

Where (i=0,1,2,...,M-1; j=0,1,2,...,N-1)

Among them, Mask is a two-dimensional matrix of M x N.

- As shown, calculating the High frequency component image I_{hf}

$$I_{hf}(i,j) = I(i,j) - I_{blur}(i,j) \quad (7)$$

Where (i=0,1,2,...,M-1; j=0,1,2,...,N-1)

- As shown in that calculating the sharpened image I_{sharp}.

$$I_{sharp}(i,j) = I(i,j) + k \times I_{hf}(i,j) \quad (8)$$

Where (i=0,1,2,...,M-1; j=0,1,2,...,N-1)

Where k is the superposition coefficient.

- As shown in the original image I is merged into the sharpened image I_{sharp}.

$$I_{sharp}(i,j) = \begin{cases} I(i,j), & if\ Mask(i,j) = 1 \\ I_{sharp}(i,j), & if\ Mask(i,j) = 0 \end{cases} \quad (9)$$

Where (i=0,1,2,...,M-1; j=0,1,2,...,N-1)

D. Image Fusion

After CLAHE enhancement and USM sharpening, the edge, shape and other details of the security X-ray image have been enhanced, but the processed image has a large color difference from the original image, which is not conducive to the security personnel to identify the items in the image.

Therefore, as show in this paper fuses the sharpened image with the original image according to the coefficient, and reduces the color distortion of the image I_{final} obtained by the algorithm in this paper compared with the original image.

$$I_{final}(i,j) = C_{sharp} \times I_{sharp}(i,j) + C_{origin} \times I(i,j) \quad (10)$$

Where (i=0,1,2,...,M-1; j=0,1,2,...,N-1)

Among them, C_{sharp} and C_{origin} are the fusion coefficients of the USM sharpened image and the original image, respectively.

3. Experimental Verification

E. Experimental Platform and Dataset

This experiment was performed on the Huawei MateBook 13, the configuration is CPU: Intel(R) Core (TM) i5-8265U, 4 cores, clocked at 1.6GHz, graphics card: Nvidia GeForce MX1502, video memory 2GB, memory 8GB, operating system: Window 10 (64-bit). The software platform uses Matlab R2016a.

Manually check common contraband items such as simulated guns, mobile phones, lighters, blades, beverage bottles, folding knives, etc., at different angles in different positions of suitcases, handbags, backpacks, etc., and then use our school security check the security inspection X-ray machine in the training room is used for image acquisition. The X-ray machine model is FISCAN® CMEX-B6550S of the Public Security No. 1 Institute. A total of 2380 X-ray images were collected and stored in the computer in JPG format. These images will be used for development. The experimental dataset. Some dangerous goods images in the dataset are shown in "Fig 1".

Fig 1: Dangerous goods image dataset.

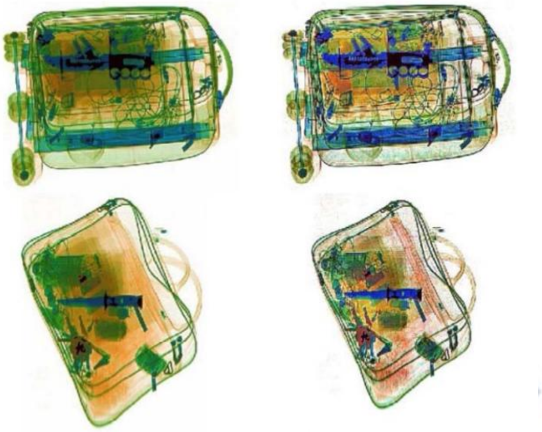

Fig 2: Enhanced Results

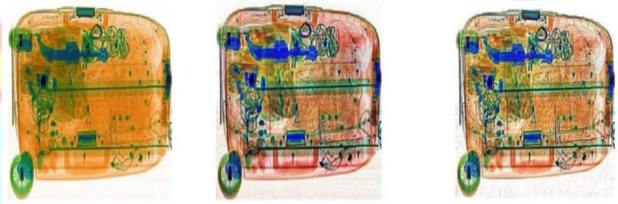

Fig 3: Comparison of the Proposed method and the enhancement effect of CLAHE.

If you are using *Word*, use either the Microsoft Equation Editor or the *MathType* add-on (http://www.mathtype.com) for equations in your paper (Insert | Object | Create New | Microsoft Equation *or*MathType Equation). "Float over text" should *not* be selected.

F. Experimental Result

Use the algorithm in this paper to enhance the data in the data set, and then manually evaluate the effectiveness of the algorithm in this paper. The experimental parameters are: the size of the sub-region in the CLAHE algorithm is 8×8, the truncation coefficient $\alpha$is 0.4and the maximum slope S_{max} is 4. In the USM algorithm, the Gaussian kernel size is 3×3,the variance is 36,the superposition coefficient is 9, and the kernel size 4. Experimental results show that the algorithm in this paper has a significant effect on most X-ray images in the data set, and some image enhancement results are shown in "Fig2". In the enhanced image, the dangerous goods and other items in the luggage are enhanced, making the image clearer and easier to distinguish.

To further verify the effectiveness of the method in this paper, the enhancement effect of the method in this paper is compared with that of the CLAHE algorithm. Some comparison results are shown in “Fig 3”.

According to Fig 3, it can be seen from that because there is no sharpening and image fusion processing, although the CLAHE algorithm can enhance the X-ray image to a certain extent, the enhanced image has serious color distortion and blurred edges. In addition, the CLAHE algorithm will enlarge the background in the original image noise. The color fidelity and edge details of the image enhanced by this algorithm are better than the CLAHE algorithm. The method in this paper cannot eliminate the background noise in the original image. How to eliminate the background noise while enhancing the image is the important work of this algorithm in the future.

4. Conclusion

This paper uses Matlab as the experimental platform to study the problem of "airport security X-ray image enhancement"and proposes an image enhancement algorithm of USM+CLAHE. This algorithm can significantly enhance the X-ray image of common items in airport security check and can effectively suppress the color distortion of the image after enhancement. It is an effective image enhancement algorithm. The next step will be to optimize the algorithm to further improve the image color fidelity and eliminate background noise.

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Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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