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IR and Multi Scale Retinex image Enhancement for Concealed Weapon Detection

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Abstract

A Concealed Weapon Detection (CWD) had been developed by a large number of researchers and technologies. As a result of the weakness of the infrared images in unique altogether graphic items, infrared and MMW images become inaccurate and insufficient to obviously detectand deal withweaponry objectsin an invisible setting. This article uses Multi Scale Retinex and contrast stretching image processing enhancement techniques to improve the recognition of weapons concealed below attire. Specifically, the focus of the study is on detecting weapons and ammos by enhancing the IR pictures based on image processing techniques. Evaluation techniques were empirically proved to be able to show the enhancement percentage progress.

Keywords: Concealed Weapon Detection, IR, and Multi Scale Retinex

1. Introduction

Nowadays, threats to human safety areunceasing to intensifyaround the world. Therefore, securing as an efficient way to ensure human safety is becoming one of the most serious concerns for authorities. Likewise,recently, weapon detection has become one of the most sensitive issues around the world. It has also turned to be an urgent issue that must be attended to in terms of safety and security purposes [1]. Regarding this, many different ways and techniques such as handguns, blades, explosives, chemicals and as well as weapon's ammoshave been developed for the purpose of detecting different types of weapons. Over the years, several image fusion methods have been proposed to meet the necessities of altered applications. One of these applications that aim to detect all multi types of weapons are IR sensors which basically use the temperature spreading to be spotted directly on the target to produce an IR image [2]. In fact, IR images are regularly used for different purposes of nightvision applications, perhaps observing sable and movable targets (i.e., people and vehicles). The infrared radiationemitted from a unfix object is engaged by clothing and then it is re-emitted**.** For thisparticular reason, the IR image can be used for presenting the image of the hidden target. However, due to the drawback of the IR images in distinguishing all visual items, IR images are still inccurate and insufficient toclearly detectand allocate or target the location of an invisible weapon. For this main reason, IR detecting devices are not enough to detect the hidden objects in accurate way and efficient detection.

The use of Concealed Weapon Detection (CWD) is basically dependent on the abilities of the hardware equipment that should be able to provide or meet somemajor requirements of CWD including being capable of penetrating and detecting objects hidden under thick cloths, being able to be used from a long range, and providing the analysis result immediately or at least simultaneously. Yet, hardware equipments are unable to cover and meetall these requirements together at the same time. For instance, the millimeter wave sensor (MMW) is claimed to be decently capable of distinguishing weapons under thick cloths but it hasits highdownside in terms of itslong range detection ability [3]. In addition, although infrared sensor (IR) has been able to overcome this problem or shortcoming of MMW, it still has drawbacks

including its ability topenetrate thick cloth. Comparatively, software development has been found and reported to be much easier and better to meetall the requirements of concealed weapon detection as compared tothe hardware equipment, and it has showed the same improvements ofthe hardware equipment in terms of saving costs, time consuming and results analysis.Many IR image enhancement techniques have been applied to enhance IR captured images like double-density dual-tree complex wavelet transform (DDDTCWT) [4], homomorphic filter [5], SIFT, Histogram thresholding and matched filtering [6]. Learning Vector Quantization (LVQ) network proposed by [5] included designing a hardware high frequency mechanism, but the disadvantage of this method is its high cost of building and designing the model. Therefore, based on all these previously highlighted issues,this work reported in the current paperproposes a better solution to solve the issuesand drawbacks of the previous methods by introducing the application of a more effective and better detection method toenhancing the captured image, as explained below.

In this research, we present a new method to enhance the captured IR images by applying Multi scale Retinexon a V color channel. For this, the the V color channel was divided into non-overlapping blocks by the size of 64x64, and block was enhanced separately. Moreover, we measured the features of each block and applied a method called "exposure" to distinguish between the dark and the bright regionsin order to be able to detect the hidden object more clearly. We also made the dark region darker and the bright region brighter to be able to highlight the hidden object.

2. Related Work

Many previous researchers have proposed and developed image-related tools or techniques for enhancing concealed weapon detection. An automatic registration algorithm for IR and MMW images was been presented by [1]. This method is based on the work rigid body transformation. Otherwise, it will not be able to make the whole body visible. While other authors havedealt with X-Ray images database to detect hidden objects [7], this method only focused on detecting a few types of ammos using simple image enhancement technique, and ignored detection of all other types of objects. In [4], the researchers introduced two decision methods which significantly improve the image fusion performance for concealed weapon detection application. Furthermore, standoff distance issue during the rush hour in airports was solved by [5] by applying homomorphic filter on blocks and blending for image fusion. Artificial Neural Network ANN method based on the PCA was introduced by [8]. A three dimensional near field imaging algorithm alsoused to compare near field simulation wasproposed by [9]. An automatic detection and recognition system of concealed weapons using sensor technologies and image processing was introduced by [10]. Millimeter-wave imaging Radiometer Equipment (MIRAE) by applying a dielectric aspheric lens and a metal mirror as a reflector, 30 channels and an FPA receiver base on the conversion type was proposed by [11].

3. Methodology

Concealed weapon detection might not detect a certain weapon and it will only be able to make such weapon appear in the captured image. Thus, measuring the histogram of every captured image does not occupy the whole dynamic range. The captured images usually suffer from an over-saturation problem, low contrast, non-uniform illumination and uneven lightening. All these problems affectthe ability to detect a hidden object. Therefore, measuring the histogram of the captured image that shows the underlying intensity exposition may occupy more of the lower part or the upper part of the total range of the histogram of the captured image. When the gray levels of the captured image contain most of the lower part of the histogram area, then, the region appears dark while it appears very bright when its cray level occupiesmore of the upper of the histogram. Some parts of the image might also suffer from being overexposed regions whereas other parts of the image can be underexposed at the same time. Hence, the image area that it suffers from an overexposed region or an underexposed region may carry less information than the image with a well-exposed region. To overcome this problem, we fused the exposure of the captured image so that the dynamic range of it.In would be enhanced. Figure 1 illustrates the processing steps of the proposed method followed in the current study.

3.1. The Proposed Method

Generally, to process the captured visual image, it was converted into HSV color space by separatingthe chromatic information and the achromatic information, and leaving the IR computed image as it is. The proposed method of this study was applied following the following eight steps:

1. Converting the input visual image in to HSV color space.
2. Enhancingthe IR image and the visual image using the MSR method that can washout the degraded image and the non-uniform lighting.
3. Dividingthe output enhanced image into 64x64 non-overlapping blocks.
4. Using the V space color from the HSV and fusingit together with the enhanced input IR image.
5. Extracting the features of each block of the fused image.
6. Determining or distinguishing between the dark and bright region to enhance the over and under-exposed problem for each block using the exposure method.
7. Extracting the histogram of the divided image using contrast stretching.
8. Re-combiningthe three channels, HSV,converting it back to the original form and getting or obtaining the enhanced output image.
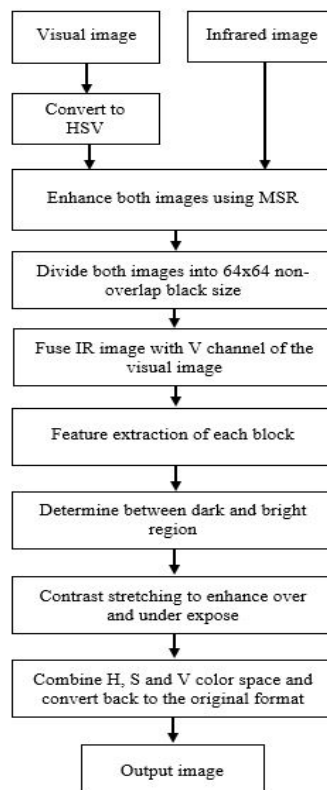
These steps are explained in more details as follows:

Figure 1. The proposed method processing

3.2. Multi Scale Retinex

Multi Scale Retinex is a method used to enhance the images which areaffected by a low contrast, uneven contrast and illumination. This method basically works on two major factors which are: illumination and reflectance. Using the Multi scale Retinex method as proposed and presented by [12-17], the image is composed by two major parts which are light and reflectance of the object as shown in Equation (1):

$$L = R/E \tag{1}$$

Where, L: the value of incident light; R: the value of object's reflection; E: the value of reflected light.

MSR is a combination of the weighted sum of the output of different sizes of scales of Single Scale Retinex (SSR) [18-20]. MSR was used in this study to enhance the input image by solving the low contrast and uneven issues of it.

MSR can be illustrated in Equation (2):

$$\text{RMSRi} = \sum_{n=1}^{N} w_n\, R_{n_i} = \sum_{n=1}^{N} w_n\, [\log\,(\text{Ii}(x,\,y)) - \log\,(\text{Ii}(x,\,y) * \text{Fn}(x,\,y))] \tag{2}$$

Ri(x, y): is the Retinex output; i: ∈ R,G,B color channels; Ii(x, y): is the input image which been distributed amongthe three channels RGB.F(x, y): the surround function.

*: mathematical convolution operation between Ii(x, y) and F(x, y); where $F_n(x, y)$ can be explained in Equation (3).

$$F_n(x, y) = C_n \exp[-(x^2 + y^2)/\sigma_n^2] \tag{3}$$

$F_n(x, y)$: The surround function.

σ_n: is the Gaussian distribution function which was fixed by the authors to 15, 80 and 250.

C_n: is the normalized factor $\iint F(x, y)d_x d_y = 1$.

Figure 1 shows the diagram of MSR algorithm which used the Gaussian function with the three scale sizes.
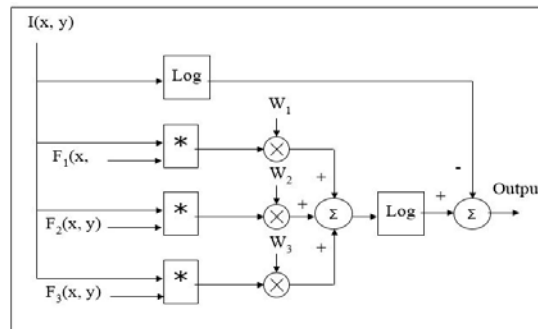

Figure 1. Multi-Scale Retinex block diagram

3.3. Dividing into Blocks and Measuring Feature Extraction

After MSR application to the input images (over-exposed and under-exposed images) was accomplished, this stage focused on regulating the best exposed images. This was conducted by isolating the image into non-overlapping 64x64 block size and classifying each block separately into overexposed, underexposed and well-exposed blocks using the exposure [21].

3.4. Feature Extraction

This was achieved by measuring the features of each block separately using three intensity features and computing them for each block for the whole image. The features are minimum intensity, maximum intensity and average intensity. The feature extractionis illustrated in the following Equations (4,5,6):

$$Minimumintesity = \min \sum_{q=0}^{l-1} qp(q) \tag{4}$$

$$Maximumintesity = \max \sum_{q=0}^{l-1} qp(q) \tag{5}$$

$$averageintesity = \frac{1}{\sum q} \sum_{q=0}^{l-1} qp(q) \tag{6}$$

Where, q: the number of the distinct gray level of each block; p(q): image histogram; I: intensity level

The average intensity is the average pixel value which is able to determine the brightness or darkness of the blocks while the minimum and maximum intensities are able to define the minimum and maximum intensities value of each block.

After measuring the exposure, minimum intensity, maximum intensity and average intensity of each block, then each block would have its own exposed area, either over, under or well-exposed. For this, we used or applied contrast stretching to the overexposed or underexposed blocks only based on the histogram of each block while ignoring the well-exposed blocks. Contrast stretching was used to change the brightness level for the selected blocks only based on this Equation (7):

$$\hat{I}_x = \frac{I_x - I_{min}}{I_{max} - I_{min}} \times 255 \tag{7}$$

Where $,I_{max}$ and I_{min} values are taken from equations (4,5).The output of each enhanced block was combined together to build the output image, and the H, V and S channels were combined together to get the output enhanced image.

4. Results and Discussions

This section discussesthe major results of our experiment that focused on proposing the adaptive enhancement partition blocks based on MSR and contrast stretching. As previously stated, the proposed method basically works on two types of image: infrared and visual images. It is able to transform the input visual image into the hue-saturation-value (HSV) color space and enhance the V channel which only contains the brightness information of the images. Based on the results, applying the Multi Scale Retinex enhancement method could achieve both: enhancing the input images and restoringthe degraded image by non-uniform illumination. Dividing the image into 64x64 non-overlap blocks enabled us to determine or distinguish among the over-exposed, under-exposed and well-exposed blocks by applying the exposure, minimum intensity, maximum intensity and average intensity that coulddetermine the dark and bright region. In this study, image fusion was applied by combining the three channels of HSV color space and converting it back into the original form to have the output enhanced image. Figure 3 shows the original image borrowed from [5], HSV image and the histogram of each one of them.
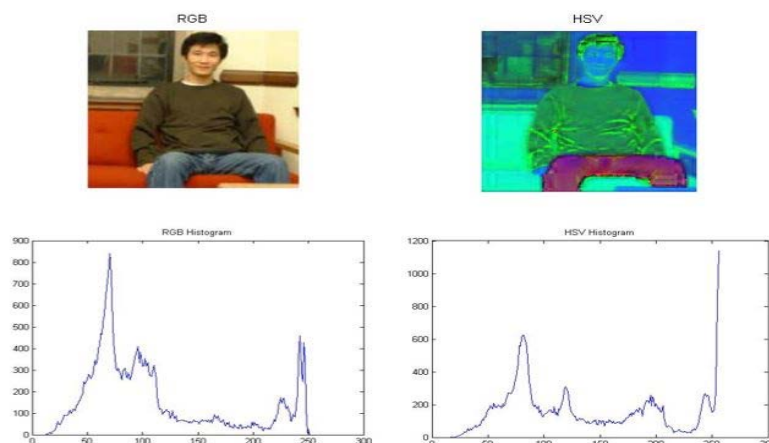

Figure 3. Original image in RGB and HSV color space and its histogram

In comparing between the image before enhancement and after enhancement byapplying MSR and contrast stretching to the output image (Figure 4), it is evident that the entropy measurement for the original visual image was5.3535 while the entropy for the enhanced image improved to be 5.1068. Our experiment provides evidence of the ability of the proposed method to enhance or improve the IR original image from 0.13229 to 0.06079.

Table 1. Proposed method results

Method	Entropy
Original image	5.3535
IR method	5.2265
Proposed method	5.1068

Figure 2. IR image before enhancment and after enhancment using MSR and Contrast Streaching
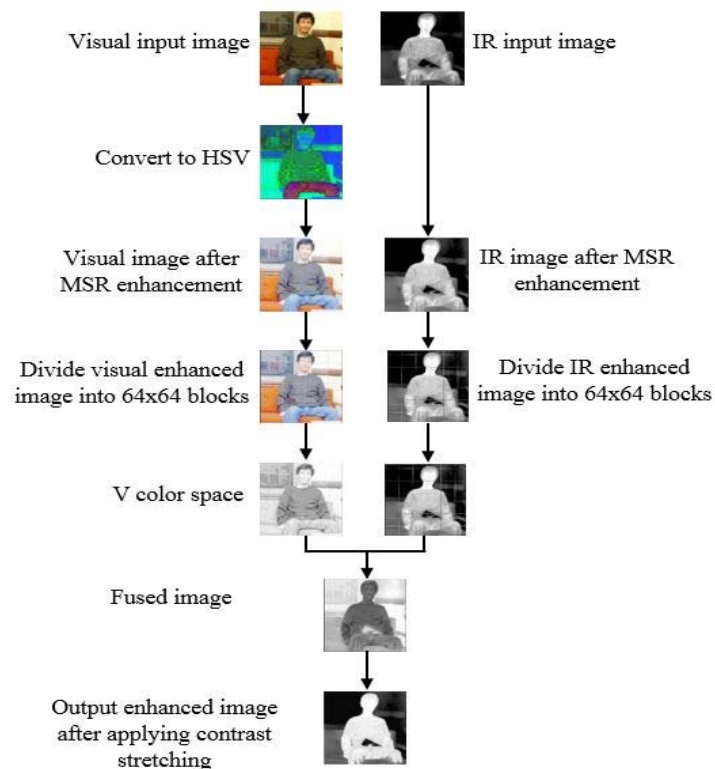

Figure 3. Proposed method process stages

5. Conclusion

In this paper, we presented a proposed algorithm for image enhancement of concealed weapon detection. Being motivated to solve serious issues including non-uniform, low contrast over-saturation problems from which infrared and visual images still suffer, the Multi Scale Retinex algorithm was proposed and applied in this study. This was carried out by dividing the image into blocks to determine the dark and the bright region and using 64x64 non-overlap

blocks to enhance each block individually. The results showed that applying contrast stretching was able to solve the overexposed and under-exposedimage issues. In addition, converting the visual image into the HSV color space was proved tobe able to provide faster processing time by enhancing theV space only compares to the use of the RGB color space. The experimental results indicated that ourproposed method was able to generate better result compared to the images taken by the IR sensors, or MMW sensors. In conclusion, our experiment inenhancing the visual image and the IR image using Multi Scale Retinex and contrast stretching has beensuccessfully achieved by applying the exposure, enabling us to determine the dark region and bright region by making the bright region brighter and the dark region darker. This work can be further developed to another stage using detection methods like applying artificial neural networks techniques.

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