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Channel Based Color Fusion of Visual and IR Images

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ABSTRACT: Images of the same scene obtained from visual and thermal camera present complementary information to each other, as both the cameras capture the images following different phenomenon. Thus prominent features of the images are combined into a single image that is suitable for human and machine perception. In this paper pixel level image fusion using weighted average and channel-based color fusion has been implemented and demonstrated using MATLAB. Different performance matrices are calculated to evaluate the performance of image fusion techniques. It has been concluded that color fusion method results are realistic and improves the observer performance and reaction time.

Keywords: Visible Image; IR image; Image Fusion; Channel based color fusion

I. INTRODUCTION

In recent years there has been a rapid improvement in the image processing techniques. The use of image processing in military surveillance and medical imaging has been rapidly done. The reason for using multiple images is that we can use prominent features of both the images to raise the detection and recognition probability. Combining two or more images of the same scene obtained from different sensors, a surveillance system can perform better than a system that uses only a single sensor image [1]. This process of combining relevant information of two or more images obtained from different sensors to create a single composite image of higher spatial resolution as compared to the images acquired by multi-sensors while preserving their spectral information is known as Image Fusion. The image obtained after fusion improves the image information, lucidity and resolution which is extremely useful to in the execution of computer vision tasks or to improve observer performance [2].

In this paper we focus on the fusion process of visible and infrared images. Visible images in this paper are captured from SP-V980HA high speed dome camera. Visible images represent the intensity of the light reflected by object in presence of illumination, within the visible spectrum. The thermal images used in this paper are captured from 3rd generation MWIR thermal imager based upon high resolution InS6 FPA. Thermal images pixel values represent the intensity of light emitted by the object, but inside a certain infrared region of the spectrum [3]. Under the poor-lighting conditions and also in case where the target and background are of the same color, thermal images help in detection and reorganization of heat-based targets [4,5]. The resulting fused image must meet the following three requirements to achieve a good fusion

1. Targets in the IR image must be perfectly preserved in the fused image.
2. Pixel values of the visual image must not contaminate the non-target pixels of IR image.
3. Information in the fused image should be enhanced, to be easily understood by the observer [3].

In this paper, weighted average fusion and channel based color fusion methods are discussed. The methods are aimed at preserving the spatial detail of an image and viewing targets clearly in the resulting image. In weighted average method, the pixel value of the fused image is calculated by weight determination function. Equal weights will generate an average of the two images whereas different weights will result in an image with more emphasis on the image of higher weight, thus here equal weights are taken. Channel based color fusion on the other hand is a fast method for real-time applications. Color fusion here means combining multispectral images into a color version image with the purpose of resembling natural scene. A color image consist of 3 channels, different combination of images is presented into these 3 channels to obtain the color fused image.

II. IMAGE PRE-PROCESSING

The original IR image captured from the thermal sensor is not used for target recognition directly, since the infrared imaging environment is very complex [7]. Also with the movement of the target object the image quality can be degraded to a greater extent. Due to the physical limitations of the sensor low contrast images can result from poor illumination, lack of dynamic range in the imaging sensor, or even the wrong setting of lens aperture during image capturing [8]. Due to this image denoising has become an important issue to enhance the image performance and target recognization.

Standard image preprocessing techniques such as Gaussian filtering, Wavelet based denoising, Image normalization and Image enhancement can be used. Here we use a general Image normalization also known as Contrast Stretching to make the images suitable for further processing. Contrast stretching is a process which expands the intensity levels range of an image so that it spans the full intensity range of the display device [5].

$$I_N = (I_o - I_{min}) \frac{O_{max} - O_{min}}{I_{max} + I_{min}} + O_{min} \quad (1)$$

Where, I_N is the normalized image, I_O is the original image, I_{min} and I_{max} are the minimum and maximum pixel values in I_O respectively. O_{max} and O_{min} are the expected maximum and minimum values in I_N which are equal to 255 and 0 respectively [5].

Generally, a linear enhancement such as Piecewise contrast stretching is used, in which the image is divided upon different intensity levels and each piece is transformed by a different linear function.

The next step is Image Registration which is required for image fusion and colorization techniques. In general, Image Registration is a process of aligning multiple images of same scene obtained from different sensors by performing necessary transformations.

III. IMAGE REGISTARTION

Image Registration is an important step in all image processing tasks in which the final information is gained from the combination of various data sources like image fusion, colorization and multichannel image restoration [8].

Image Registration is a process of aligning two or more images of the same scene captured from same or different sensors, taken during different times and viewpoints. In this case one image is considered as the base image, while other as an input image. The input image is aligned to the base image by applying necessary transformations such as translation, rotation, affine and projective etc. Here we have used affine transformation which is a combination of scaling, translation and rotation.

Image Registration techniques are basically classified as intensity based and landmark based also known as local point mapping method. Both the methods have their own advantages and disadvantages. Here we are using local point mapping method in which the control points are selected manually. Since the image formation process of both visible and infrared camera is different, thus we find great difficulty in using intensity based process as well as automatic point mapping method. The manual selection of the control points is a time consuming task and requires user interaction while automatic selection of landmarks is a challenging problem as image formation process of both visible and infrared images is different [7].

Thus here we have employed local point mapping method to register two images. The control points in both the images are selected manually upon which the affine matching transform is sought. The control points selected are known to be rigid, stationary and easily pin-pointed in both the images, typically features such as corners and line intersections are selected. As the affine transformation has 3 degree of freedom, thus we require a minimum of 3 control points to find the transformation matrix which is used to align the two images.

IV. IMAGE FUSION

Image fusion is a process of combining images of the same scene obtained by sensors of different wavelengths simultaneously, to form a composite image. The composite image thus formed improves image content and make it easier for the user to detect, recognize, and identify targets and increase his situational awareness. The research activities are mainly in the area of developing fusion algorithms that improves the information content of the composite imagery, and for making the system robust to the variations in the scene, such as dust or smoke, and environmental conditions, i.e. day or and night. Infrared (IR) and visible video sequences fusion has been widely used in many fields, such as military, remote sensing, security and surveillance, etc [9]. Since infrared sensors have the ability to identify the thermal targets, and visible sensors can provide the details of the scene, good IR target features as well as clear visible background can be achieved by fusing infrared and visible video sequences.

A. Weighted Average Fusion

Pixel-level image fusion retains more original information and high precision. At present, the commonly used methods are simply weighted average method, multi resolution pyramid method, and color space transformation method. The weighted average method is one of the most simple image fusion methods, which makes weighted processing on corresponding pixel point of multiple original images. Assume that A(i, j) is a pixel point in image A after mean filtering , and B(i, j) is the corresponding pixel point in image B after edge detection, then the fusion image pixels can be obtained by this formula:

$$C(i, j) = W_a (i, j)A(i, j)\ W_b (i, j)B(i, j) \quad (2)$$

$$W_a (i, j) + W_b (i, j) = 1$$

Value of weights W(i,j) is based on the local contrast weight selection method, i.e. for the pixel with low contrast it is 0 otherwise 1. Equal weights will generate an average of the two images whereas different weight factors will put more emphasis on one of the two images. [9]

B. Channel based Color Fusion

A fast color fusion method, termed as channel-based color fusion, was introduced to facilitate real time applications. The term of "color fusion" means combing multispectral images into a color-version image with the purpose of resembling natural scenes. The general framework of channel-based color fusion is, (i) prepare for color fusion, preprocessing (denoising, normalization and enhancement) (ii) image registration, i.e., align the visual and infrared images (iii) form a color fusion image by properly assigning multispectral images to red, green, and blue channels. Suppose a color fusion image (F_C) consists of three color planes, F_R, F_G, F_B, the color fusion of Visual and Infrared images are formed by using the following expressions,

1) $F_R = S_{[0,1.0]}^{[0,0.7]}$ (registered image)

$F_G = S_{[0.1,I\_G_{max}]}^{[0.2,1]}$ (visual image)

$F_B = S_{[0,1.0]}^{[0.1,0.75]}([1.0 - \text{registered}] \bullet \text{visual image})$

2) $F_R = S_{[0,1.0]}^{[0,0.7]}$ (registered image)

$F_G = S_{[0.1,I\_G_{max}]}^{[0.2,1]}$ (visual image)

$F_B = 0$

Where, $S_{[0.1,I\_G_{max}]}^{[0.2,1]}$ denotes piecewise contrast stretching defined in Eq. (1) and $I_{G_{max}} = \min([\mu_\pi + 3\sigma_\pi], 0.8)$, μ and σ are the mean and standard deviation of visual image; [1.0-registered] is to invert registered image; symbol '•' means element-by-element multiplication. Although the limits given in contrast stretching are obtained empirically according to the multispectral images that we had, it is viable to formulate the expressions and automate the fusion based upon a set of conditions. [6]

V. EXPERIMENTAL RESULTS

A. Subjective Assessment

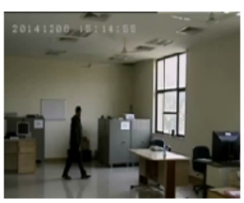
Subjective measuring method is to evaluate the quality of fused images subjectively with human vision system. This assessment is totally based upon the view-point of observer and results can vary from individual to individual. Image Registration, Weighted Average Fusion and Channel based Color Fusion results of data set are shown below.

B. Performance Metrics

Since Objective assessment is totally based upon the view-point of observer and results can vary from individual to individual. Precisely because of the inevitable impact of individual difference, it's necessary to figure out a method to evaluate the fused images in a objective and mathematical way, which is so called 'Objective measuring method'.

Table 1: Evaluation Result of Fusion Techniques.

Fusion Techniques	**Entropy**	**Standard Deviation**	**Fusion Root Mean Square Error**	**Correlation Coefficient**
Weighted Average Fusion	5.440	45.180	0.987	40.079
Channel based Color Fusion 1	7.407	50.680	0.989	43.295
Channel based Color Fusion 2	7.322	58.191	0.999	52.302

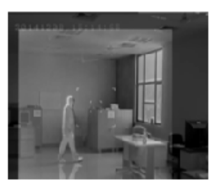


(a)

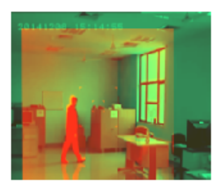
(b)

(c)

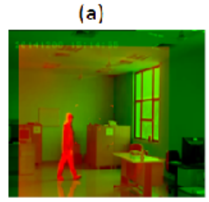
Figure 1
(a) Input visible image
(b) Input infrared image
(c) Registered image



(a)



(b)



(c)

Figure 2
(a) Weighted Average Fused image
(b) Channel based Color Fusion 1 image
(c) Channel based Color Fusion 2 image

VI. CONCLUSION

From obtained results i.e. form both subjective and objective assessment it can be said that the channel based color fusion gives reasonable coloring results as compared to the individual multispectral images and can be implemented for real-time applications. The colorized multispectral imagery can significantly enhance the vision of human users and will eventually lead to improved performance of remote sensing, night time navigation, and situational awareness.

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