Color Based Grayscale-fused Image Enhancement Algorithm for Video Surveillance

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Abstract

Multiple sensors image fusion is increasingly being employed in video surveillance. This paper presents a color based grayscale-fused image enhancement algorithm. The main advantage of this algorithm is to stand out meaningful information of a certain sensor in selected band of the color space, while maintain the high resolution of the grayscale-fused image. Moreover, a performance evaluation method based on analyzing the average gradients of the color-fused image is presented and experiments are performed using images under complex environment. The results show that the addition of color to grayscale-fused image can significantly increase observer's sensitivity and the accuracy of further classification and recognition.

1. Introduction*

Multiple sensors image fusion is increasingly being employed in video surveillance. The two most common image sensors in this application field are IR and CCD, although modern IR cameras function very well under most circumstances, they still have some inherent limitations. For example, the infrared bands provide less detailed information in low thermal contrast area in the scene, whereas the visual bands may represent the background in great detail. The objective of image fusion here is to combining complementary information from those two sensors to generate a single image that contains a more accurate description of the scene than any of the individual image for the better understanding of human visual system or automatic computer detection and classification.

To combine the complementary information from multiple sensors, a variety of image fusion algorithms have been developed over the past several years, and the typical techniques are multiscale-decompisition based image fusion methods [1,2,3,4,5],such as pyramid based methods [3] , discrete wavelet transform based methods [4] and etc. The multiresolution grayscale image fusion method selects the perceptually most salient contrast details from both of the individual input image into a fused image. So details in it can be displayed with higher contrast than they appear in any original images. However, this grayscale-fused image doesn't distinguish where the information comes from. For example, it can't separate the visible edges from the thermal edges and thus it can be hard or even impossible to distinguish the targets owned high temperature which are always the area we should pay more attention to.

In order to overcome this problem, some researchers map images of several sensors to different channels to produce a color-fused image. A.Toet [6] produced the fused image through a grayscale pyramid image-merging scheme, in combination with two different color mappings in YIQ color space. Zhiyun Xue[7] fused color visual image and a corresponding IR image for such a concealed weapon detection application in HSV and LAB color space. Aguilar et. al [8] used neural network to fuse a low-light visible image and a thermal IR image to generate a three-channel false color image used for night operation.

In this paper, we present a new color based method for grayscale-fused image enhancement. One advantage of our method is it can combine meaningful information of a certain sensor in selected band of the color space, while maintain the high resolution of the fused image. Another one comes from the biological research results that human visual system is very sensitive to colors , as a result, the addition of color to grayscale-fused image can significantly increase observer's sensitivity and the accuracy of further detection and classification.

Moreover, based on analyzing the average gradients of the color-fused image, a performance evaluation method is presented which also improves that our color based grayscale-fused image enhancement algorithm dose well .

The remainder of this paper is organized as follows. Section 2 describes the proposed color based grayscale-fused image enhancement algorithm. Section 3 explains the performance evaluation algorithm. Section 4 presents the experimented results which demonstrate the feasibility of the proposed method under various conditions. Section

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5 contains the summarization of the paper and discussion of future extensions.

2. Color based grayscale fused image enhancement

The flow diagram of the proposed algorithm is shown in Figure1. Firstly, the input visual images of different sensors denoted as I_{rgb}^{i} , $i=1,...,N$ are all sent to a fusion module, in which many typical fusion techniques can be selected according to the different application fields. The output grayscale-fused image denoted as F_g in this module contains high contrast details of the scene. To combine the thermal information of a certain sensor in the final color-fused image, F_g is transformed from RGB color space into HSV color space, the H-channel of F_g, which represents the color of the image, will be modulated in the color enhancement module with the input visual image from a selected sensor. The S-channel which shows the saturation will be set to a certain value, and the V-channel, carry high contrast details information, will be used directly in the final color fused image F_c.

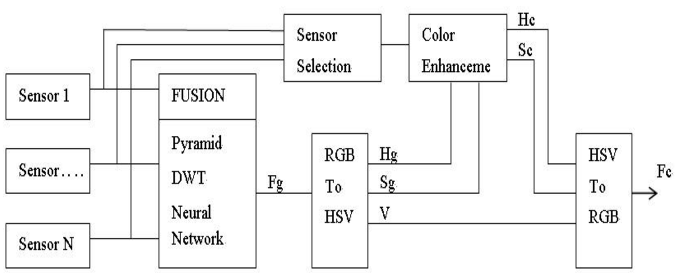


Figure 1. The block diagram of the algorithm

As we have mentioned above, many techniques can be used in the first fusion step. In our experiments, we selected the DWT (discrete wavelet transform) based method. The DWT based method is one of many possible multiscale-decomposition-based (MDB) fusion methods. It consists of three main steps. First, each source image is decomposed into a multiscale representation using the DWT transform. Then a composite multiscale representation is constructed from the source representations and a fusion rule. Finally the fused image is obtained by taking an inverse DWT transform of the composite multiscale representation. The fusion rule we used is choosing the maximum value of the coefficients of the source images for the low frequency band and the high frequency band. At last, the grayscale-fused image F_g is produced by applying the inverse DWT.

After obtaining the grayscale-fused image F_g , a transformation from RGB color space to HSV color space is applied. The main objective of the color modulation module is using the intensity value of a certain sensor to modulate the H-channel and S-channel of the F_g. The new H_c and S_c are obtained by carrying out the following procedures.

$$\alpha(x,y)=\frac{I^{i}(x,y)-\min(I^{i})}{\max(I^{i})-\min(I^{i})} \quad (1)$$

$$H_c(x,y)=\alpha(x,y)\cdot(h_{end}-h_{start})+h_{start} \quad (2)$$

$$S_c(x,y)\equiv 1 \quad (3)$$

where $I^{i}(x,y)$ denotes the intensity value of the selected sensor image, $\alpha(x,y)$ is the modulate coefficient. h_{start} and h_{end} represent the starting and ending point of selected band in the color space.

Finally, through combing the modulation results H_c, S_c and the V-channel of the grayscale-fused image V_g, the final color fused image F_c is created and transformed from HSV color space to RGB color space.

3. Performance evaluation

Assessing image fusion performance in a real application is a complicated issue. A good fusion algorithm should preserve or enhance all the useful features from the source images, not introduce artifacts or inconsistencies which will distract human observers or the following processing, and eliminate noise and provide robustness against registration errors. Considering the main objective of our method, we are focusing on whether our color-fused image maintains the high resolution of the gray fused image while display special features of a certain sensor.

We employ the three average gradients of column, row and the whole image to compute and compare the resolution changes. Different to gray image, the intensity value of the pixel in color image is a vector with three Dim, here we use Di Zenzo 's method [9] to calculate the gradient. Let $g_{i,j}^{\theta}$ denote the gradient of a pixel at (i,j) in the direction θ.

$$g_{i,j}^{\theta}=\sqrt{\frac{1}{2}\left[(g_{i,j}^{x}+g_{i,j}^{y})+(g_{i,j}^{x}-g_{i,j}^{y})\cos 2\theta+2g_{i,j}^{xy}\sin 2\theta\right]} \quad (4)$$

where θ denotes the direction of the maximum changing value of the pixel intensity. $g_{i,j}^{x}$, $g_{i,j}^{y}$ and $g_{i,j}^{xy}$ represent gradient in different directions.

$$\theta = \frac{1}{2}\arctan\left[\frac{2g_{i,j}^{xy}}{g_{i,j}^{x} - g_{i,j}^{y}}\right] \tag{5}$$

$$g_{i,j}^{x} = \left|\frac{\partial R}{\partial x}\right|^2 + \left|\frac{\partial G}{\partial x}\right|^2 + \left|\frac{\partial B}{\partial x}\right|^2 \tag{6}$$

$$g_{i,j}^{y} = \left|\frac{\partial R}{\partial y}\right|^2 + \left|\frac{\partial G}{\partial y}\right|^2 + \left|\frac{\partial B}{\partial y}\right|^2 \tag{7}$$

$$g_{i,j}^{xy} = \frac{\partial R}{\partial x}\frac{\partial R}{\partial y} + \frac{\partial G}{\partial x}\frac{\partial G}{\partial y} + \frac{\partial B}{\partial x}\frac{\partial B}{\partial y} \tag{8}$$

After obtaining the gradient of the pixel in the image, the average gradient of the column, row and the whole image $\bar{f}_i, \bar{f}_j, \bar{f}$ are calculated.

$$\bar{f}_i = \frac{1}{n}\sum_{j=1}^{n} g_{i,j}^{\theta} \tag{9}$$

$$\bar{f}_j = \frac{1}{m}\sum_{i=1}^{m} g_{i,j}^{\theta} \tag{10}$$

$$\bar{f} = \frac{1}{m \cdot n}\sum_{j=1}^{n}\sum_{i=1}^{m} g_{i,j}^{\theta} \tag{11}$$

Experiment results demonstrate that those parameters above are effective and efficient in dealing with color image resolution changes decision, and its evaluation result is almost same to that of the human visual system.

4. Experiment results

In order to illustrate the effective and efficiency of the proposed color based fused image enhancement algorithm, a group of typical images were used in the experimental tests. These test images are selected to test the enhancement algorithm of IR and CCD under complex application conditions.

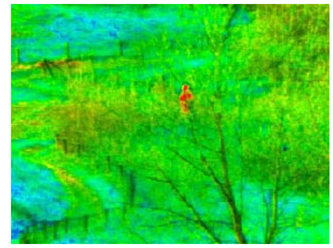
Figure 2 (a) shows the original CCD image in a very complex scene and a person is standing behind trees who is invisible in the CCD original sensor image. Figure 2 (b) shows the IR image. According to the person's high temperature which differs sufficiently from the mean temperature of its local background, the person is easily detected in the IR image. Figure 2 (c) shows the grayscale-fused results used DWT fused method. Figure 2 (d) is the result of our method. Because of the high contrast of the background (trees and grasses), the person is almost invisible in the cluttered grayscale-fused image, however, after mapping the thermal information, the person is highly detectable in the color-fused image .

Figure 2(e), (f) represent the average gradient of the horizontal and vertical direction of those images above separately. In this test, the grayscale-fused image (Figure 2(c)) obtained by DWT fusion technique contains the

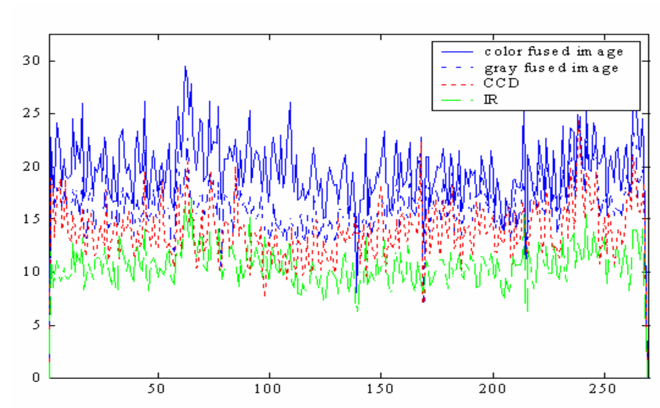
a

b

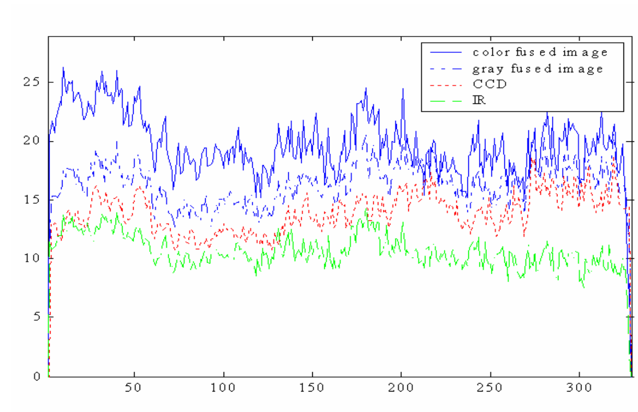
c



d



e



f

Figure 2. a)Original images(CCD). (b) Original images(IR). c) Fusion result (Grayscale-fused image). d) Fusion result (Color fused image). e) Performance evaluation(Average gradient of horizontal) f) Performance evaluation(Average gradient of vertical).

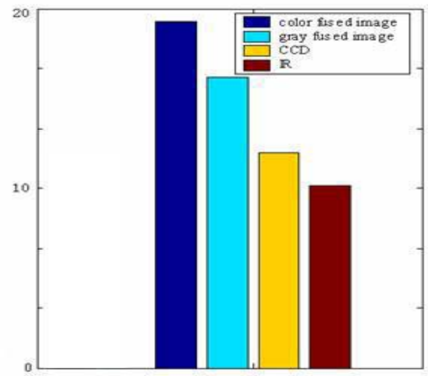


Figure 3. Average gradient of the fusion results

most salient contrast details from both of the original sensors. However this fusion process does not distinguish the visual edge and the thermal edge, as a result, it's hard for user to separate the people from the trees. In the color-fused image (Figure 2(d)), the high thermal area is shown with red color, which makes the target highly detectable. Meanwhile, the average gradients of the color-fused image in different directions (Figure 2 (e), (f)) are highest among the input and gray level fused imageries.

Furthermore, in Figure 3 ,we give the average gradient comparison about the test images. The fused image perform significantly better than CCD and IR. Moreover, the best result is obtained by the color-fused image. This performance result is similar to user's judgment. For grayscale-fused image, the observer's sensitivity is reduced because little thermal information can be found in it and it's hard for user to find the important target accurately. Color fused image restores some of the information required to perform the task. In Figure 3, for the complex background full of edges of trees and grasses, its almost impossible to detect people in the grayscale-fused image. However, in the color-fused image, which contains the temperature field of scene, it's easy for observer to find the target.

5. Conclusion

This paper has presented a novel color based grayscale-fused image enhancement algorithm. Although the grayscale image fusion yields appreciable performance in many tasks, the introduction of spurious or irrelevant contrast elements (such as visual edge and temperature edge) may clutter the scene and distract the observer and lead to misinterpretation of perceived detail. When an appropriate color based enhancement scheme is applied, the addition of color to grayscale-fused image can significantly increase observer's sensitivity and the accuracy of further classification and recognition. The algorithm proposed in this paper has the characteristic of appropriately mapping the thermal distribution of the scene in the fused image by color, while maintain the high resolution of the grayscale-fused image. The test results and the performance evaluation method we used in this paper also demonstrates that the color-fused image can significantly increase the observer sensitivity of the interested targets. Moreover, the color based fused image enhancement method mentioned here can also be used for other multiple sensors image fusion system, for instance, the medical image fusion of MR and CT sensors or the remote sensoring image fusion of multi-spectrum sensors.

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