A Modified Objective Image Fusion Quality Index

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***Abstract*—Quality assessment of fused image is a vital procedure for image fusion in the Internet of Multimedia Things. A reasonable quality index is not only able to give an accurate assessment for fused results, but also could provide a performance improvement advice for fusion algorithms. In this paper, we will mainly discuss the image fusion metric based on gradient field and improve the accuracy of objective quality assessment algorithm. All these works are making the paving for further research of more HVS conformed metric and fusion algorithm based on quality driving.**

Keywords—image fusion; index; gradient; quality driving

I. INTRODUCTION

With the development of the Internet of Things (IoT), image sensing, as the “eye” of all things, is being become an important perception interface for promoting Internet of Things applications [1-4]. It is called Internet of Multimedia Things (IoMT) when the sensor type is image sensor. One of the challenges in IoMT is the imaging quality due to limited computation resources of the sensor and huge data volume [3-4], especially in the multimodal sensors applications. To make use of the complementation information, to meet the limited computation and transmission resources, image fusion algorithm are investigated widely. Thus, presenting a high-quality fused image to the terminal clients is very necessary. The image fusion quality index proposed in this paper aims to evaluate the fusion results of different fusion algorithms. As a positive feedback, the fusion algorithm is modified to achieve a better fusion effect.

Generally speaking the fused image should retain the details of the source images as much as possible, especially the detailed textures. The objective performance assessment of fused-images is still lack of a generalized standard [6]. The UIQI [7] is a general image quality index which reflect the related property between two image patches. Based on UIQI, various quality indices [6], [8], [9] have been developed for image fusion, however there were still some issues on the definition of weight calculation for these UIQI-related indices. Edge structure information should also be taken into account, Reference [6] exploited UIQI to calculate the similarity of intensity of gradient field. Nevertheless, UIQI only reflect the modulus structure relationship of gradient information between two images. Reference [10] Xydeas and V.Petrovic proposed a method to assess the quality of fused images by evaluate the similarity of direction and intensity in gradient field. Reference [2] proposed a no-reference quality metric for IoMT, but is not suitable for multimodal image fusion application.

II. METHOD OF XYDEAS

In this section, we will briefly introduce gradient-based index proposed in [10], which compares the similarity of orientation and intensity of gradient.

Assume I_i is the i^{th} input image in the total of N , and F is the fused image. A gradient operator is employed to obtain the edge orientation $\alpha(x)$ and intensity $g(x)$ information for each pixel $p(x)$ in position $x=(x_1,x_2)$, for $1\le x_1\le H$ and $1\le x_2\le W$, H and W represent the height and width of images. Thus for an input image

$$g_{I_i}(x)=\sqrt{s_{I_i}^{x_1}(x)^2+s_{I_i}^{x_2}(x)^2} \tag{1}$$

$$\alpha_{I_i}(x)=arctan\left(\frac{s_{I_i}^{x_2}(x)^2}{s_{I_i}^{x_1}(x)^2}\right) \tag{2}$$

Where $s_{I_i}^{x1}(x)$ and $s_{I_i}^{x2}(x)$ are the output of the horizontal and vertical gradient at position x of image I_i .

The relative intensity and orientation difference values in position x between image I_i and fused image F are defined as follow [10]

$$G^{I_iF}(x)=\frac{min\{g_{I_i}(x),g_F(x)\}}{max\{g_{I_i}(x),g_F(x)\}} \tag{3}$$

$$A^{I_iF}(x)=1-\frac{\left|\alpha_{I_i}(x)-\alpha_F(x)\right|}{\pi/2} \tag{4}$$

The similarity value $Q_\alpha^{I_iF}(x)$ and $Q_g^{I_iF}(x)$ are obtained from $A^{I_iF}(x)$ and $G^{I_iF}(x)$.

$$Q_\alpha^{I_iF}(x)=\frac{\Gamma_\alpha}{1+e^{\kappa_\alpha(A_{I_iF}(x)-\sigma_\alpha)}} \tag{5}$$

$$Q_g^{I_iF}(x)=\frac{\Gamma_g}{1+e^{\kappa_g(\mathrm{G}_{I_iF}(x)-\sigma_g)}} \tag{6}$$

Where $\Gamma_\alpha, \Gamma_g, \kappa_\alpha, \kappa_g, \sigma_\alpha$ and σ_g are regulation constants which are given in [10].

The edge information preservation value defined as

$$Q^{I_iF}(x) = Q_\alpha^{I_iF}(x) Q_g^{I_iF}(x) \quad (7)$$

Combining all input images I and fused image F, the index is defined as

$$Q^{I/F}_{fusion\ method} = \frac{\sum_{x_1=1}^{H}\sum_{x_2=1}^{W}\sum_{i=1}^{N} Q^{I_iF}(x_1,x_2) g_{I_i}(x_1,x_2)}{\sum_{x_1=1}^{H}\sum_{x_2=1}^{W}\sum_{i=1}^{N} g_{I_i}(x_1,x_2)} \quad (8)$$

Where $g_{I_i}(x)$ is performing the weight of $Q^{I_iF}(x)$.

III. The Improved Algorithm

As we can see in the last section, the vectorial angle is calculated by formulae (2) and (4). Using tan function to calculate the angle for each vector, then angle between vectors is obtained by calculate the absolute value of angles' difference value of each vector. But there is a problem about the tan function's domain of definition. On account of the definition domain of tan function is $[-\pi/2, \pi/2]$, there is possible of calculating the incorrect angle of vector. E.g. as shown in Fig.1, assuming we need to calculate the angle between $\vec{v}_1$ and $\vec{v}_2$, the correct angle is θ_1. If using tan^{-1} to calculate the angle of $\vec{v}_2$, the answer would be θ_2.Then, the result angle is an acute angle, but true value should be an obtuse angle.

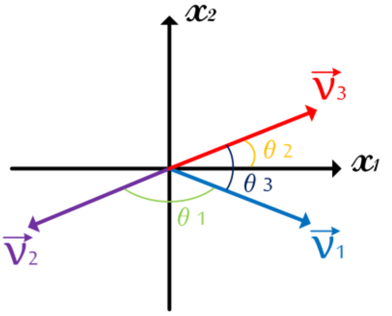

Fig. 1. Example of angle calculation.

In order to solve this problem we proposed a different angle calculate method. Assume gradient of image I_i is $\overrightarrow{Gr_{I_i}}(x) = [s_{I_i}^{x_1}(x),\ s_{I_i}^{x_2}(x)]$ in position (x), then the angle between source images I_i and fused image F in position (x) will be defined as:

$$\alpha_{I_iF}(x) = cos^{-1}\left(\frac{\overrightarrow{Gr_{I_i}}(x) \bullet \overrightarrow{Gr_F}(x)}{\left\|\overrightarrow{Gr_{I_i}}(x)\right\| \bullet \left\|\overrightarrow{Gr_F}(x)\right\|}\right) \quad (9)$$

Then

$$A^{I_iF}(x) = 1 - \frac{\left|\alpha_{I_iF}(x)\right|}{\pi/2} \quad (10)$$

According to Cosine theorem we can obtain the correct vectorial angle directly.

IV. Experiment Results

In this section, we chose a series of fusion scenarios to verify the reasonability of the modified fusion index. The result is identify as we expected. Some typical fusion scenarios will be shown in Fig. 2. Respectively are target figure in bush (S1), night scene of commercial street (S2), target on expansive ground with smog (S3) and a boat on the ocean (S4). In order to extrude the effect of indices, we chose two fusion algorithms' (NSCT [11] and DWT [12]) fused results. After experiment of subjective assessment on fused results of different algorithms, the common judgment is the results of NSCT is superior to DWT's. It can be observed from Fig.2. Since the chunk edges emerge in DWT method, the index should be relatively lower.

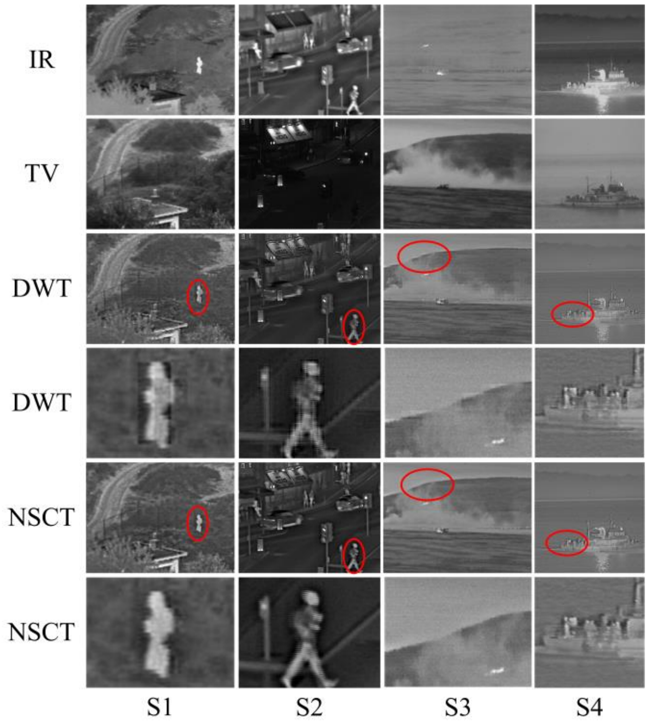

Fig. 2. Fusion results.

Fig.3 shows the fused images' index results of NSCT and DWT, (a) is indices of our method and (b) is indices of Xydeas's. As we can see the general trend of indices reveal that the fused images of NSCT is relatively outperform fused images using DWT method, and it is in accordance with the subjective assessment. In our rectified method the index is performed precisely. Note that in scenario 3 (s3), there are fake edges emerging at the ridge line of mountain in DWT method, however the fused image index of DWT is a little bit higher than NSCT's in Xydeas's method. In the proposed method, it's performed as we expected. In another word, our method is more robust than the former one.

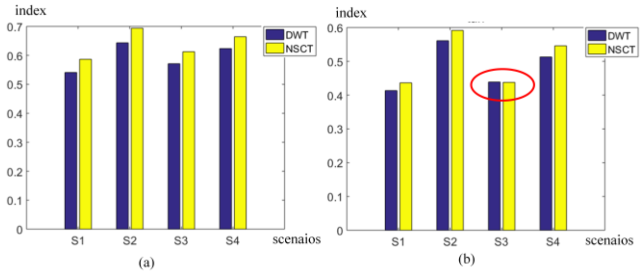

Fig. 3. Fusion results' index.

V. CONCLUSION

Performance assessment of fused image is the crucial links of image fusion, it can provide us a quick view on the performance of fusion algorithms, and furthermore a good index could give a guide line to improve algorithms. In the further research, we will study on the definition of choosing mapping parameters and the local weight of index. Combined subjective assessment, we dedicate to getting a more HVS complied fused image index.

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