The Quality Metrics of Evaluation of Image Fusion Techniques

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Abstract— In this paper we have proposed synthesizing methods for evaluation of gray-scale and colour images from same or different image sources which combines information obtain from various image sensors and gives integrated compact and more informative representation of all images in single image.

Keywords—Gray Scale image, Colour image, CIFM, CT, DWT, MRI, MERIS, PCA.

I. INTRODUCTION

The recent advancements in sensors technologies microelectronics and multisensory technology have motivated us towards processing techniques which involves combination of information obtained from many sources of images. For this combination there are number of image fusion techniques are used in the medical diagnostics, military applications etc. The main function of these fusion techniques is to generate compact representation of multiple images into a single gray scale and colour image which consist of all important and required original features that fused image will provide improved interpretation capabilities.

The performance evaluation of fusion techniques is predicted by two methods namely subjective and objectives out of which in subjective method of assessment human visual inspection is performe which is time consuming and will not give exact prediction of fused image and which led towards objective prediction of fusion methods which will rapidly compare results obtain with different algorithms which gives optimal settings for specific fusion algorithm. Depending upon objective evaluation fusion process is classified into Gray scale and colour image fusion methods.

II. IMAGE FUSION MEASURES

Image fusion measures used to assess the quality of fusion algorithm. Image fusion employs mutual and conditional mutual information in order to assess and represent the amount of information transferred from the source image to the final fused image. Accordingly, the common information contained in source images is considered only once in performance evaluation procedure.

In this paper proposed measure is based on pixel level image fusion which combines and preserve important visual information present in number of images into a single fused image thus fusion measure should have following objectives as i) It should extract all the important information exist in all input images.ii) It should measure the ability of fusion process to transfer as accurately as possible this information into single output image. In this work visual information is associated with "edge" information which is present in each pixel of image which is probably first objective image fusion measure. The evaluation of amount of edge information that is transferred from input images to fused image is employed as measure of fusion performance. By evaluating amount of edge information that is transferred from input image to fused image a measure of fusion algorithm can be obtained as.

Let us consider two images A and B and resulting fused image F Sobel edge algorithm is used in Sobel algorithm there is sobel operators to assess edge strength G(n,m),orientation a(n,m) and information for each pixel p(n,m), 1≤ n ≤ N and 1≤ m ≤ M. Thus for an input image A

\[ G_A(n, m) = \left( S^x_A(n, m)^2 + S^y_B(n, m)^2 \right)^{1/2} \]

(1)

\[ \alpha(n,m)= \arctan \left( \frac{S^x_A(n, m)}{S^y_B(n, m)} \right) \]

(2)

III. BASICS OF INFORMATION THEORY

Basic information theory explains information and the common information between images. These basics are used in various image fusion measures in order to evaluate the amount of information in each image as well as common information between two or more image H(x) is entropy or total information of image or discrete random variable X which is given as,

\[ H(X) = -\sum p(x) \log p(x) \]

(3)

Where \( p(x) \) =Probability of density function

In case of image entropy describes total amount of information in image H(X,Y) represents joint entropy or information of two images X,Y whereas p(x,y) defines joint probability function of images.
H(X,Y)= -∑x∑y p(x,y) log p(x,y)  

Whereas conditional entropy of random variables X and Y is expressed as

H(X|Y)= -∑x∑y p(x,y) log p(x|y).  

The common information shared between two random variables X,Y is expressed by mutual information which is define as

I(X;Y)= ∑x∑y p(x,y) log \frac{p(x,y)}{p(x)p(y)}  

IV. GRAY-SCALE IMAGE FUSION EVALUATION

The goal of an image fusion process is to mix number of multimodal or multispectral images into a final single image that reveals maximum possible information, which is present in the source images. In this fused image there may be overlapping of same data in fused image taken from number of image sources. For example, in the case of multispectral imagery, each band reveals different aspects of the same scene but, at the same time, a large amount of overlapping information can be seen due to texture or spectral correlation. In an objective assessment of the effectiveness of a fusion algorithm the overlapping information should be considered only once and this problem has not been addressed in the existing measures.

A. IFPM Measure

Image Fusion Performance Measure (IFPM) is an information based global measure of objective performance evaluation of image fusion algorithms. This measure provide mutual information as well as conditional mutual information in order to analyze amount of information transferred from source images to final fused image. In IFPM measure each source image Xi is considered as discrete random variable and (xi) is probability density function whereas Y is fused image with p(y) as corresponding probability density function, I(X;Y) describes mutual information that is common information, I(X2;Y|X1) delivers common information between X2 and Y given X1. It means information present in X2 is considered for evaluation of common data present in X2 and Y.

IFPM is define as,

IFPM = \frac{C1}{H(X1,X2,...,Xn)}  

Where C1=Total amount of common information which is given as,

C1=I(X1;Y) + I(X2;Y|X1) +........+ I(Xn;Y|Xn-1,..X1)  

IFPM defines information in the range of 0 and 1 in which, 0 represent lack of common information between source and fused image. 1 represent ideal case means transfer of all effective information from source image.

In order to have objective evaluation of gray scale image fusion following are the different image fusion methods.

Method1 is simple averaging of source images, method 2 is principle components analysis (PCA) algorithm which is applied on source image and first principle component is considered as final fused image whereas third method discrete wavelets transform (DWT) and final fused approach is based on multiscale morphological fusion method.

Two data sets are used to compare performance evaluation of image fusion methods in first dataset images are taken from IKONOS-2 sensors which is in the visible and near infrared region of electromagnetic spectrum whose resolution is 11 bit fixed into urban area with road network, a forest, a stadium and a park etc.

Whereas second dataset is derived from night vision area represent sandy path, trees and fences in which a person is standing behind trees and close to the fence.

Figure 1: Source image a) Natural colour composite of first three band b) Infrared band signal Resulting images of c)Averaging d) PCA e) DWT f)Morphological fusion method.
The performance evaluation of above four methods based on two different datasets based on information theory measure is given in following table,[1] which shows two types of datasets in which one dataset is taken from remote sensing element and dataset 2 is taken from night vision.

Table 1.
Objective evaluation based on IFPM and MI

<table>
<thead>
<tr>
<th>Method of fusion</th>
<th>Dataset 1 RemoteSensing</th>
<th>Dataset 2 Night Vision</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IFPM</td>
<td>MI</td>
</tr>
<tr>
<td>Averaging</td>
<td>0.2629</td>
<td>3.4755</td>
</tr>
<tr>
<td>PCA</td>
<td>0.2993</td>
<td>3.9023</td>
</tr>
<tr>
<td>DWT</td>
<td>0.3050</td>
<td>3.4318</td>
</tr>
<tr>
<td>Morphology</td>
<td>0.2434</td>
<td>1.7036</td>
</tr>
</tbody>
</table>

V. COLOUR IMAGE FUSION

The purpose of colour image fusion is to avoid the drawback of gray scale image fusion in which there is overlapping of information in fused image. Colour image fusion, Colour image fusion is formed in RGB colour space which is used by all standard display devices in this colour transformation is uniform in order to evaluate image fusion performance, assessment of effectiveness of fusion method to result in final image with maximum perceivable colour information.

An uniform colour space consist of achromatic luminosity component L* and two chromatic values a* and b* each incorporate opponent colour one way to represent colour characteristics is by transforming L*a*b* components cylindrical components such as C*ab and h*ab on a* b* plane is given by,

\[ C_{ab} = \sqrt{a^{*2} + b^{*2}} \]  
\[ h_{ab} = \tan(a^{*}/b^{*}) \]

Where,

C*ab represents Chroma signals.

h*ab represents angle related to hue.

A. CIPM Measure

The colour image fusion method assess the performance evaluation by considering amount of information transferred to final image and simultaneously variety of different colour obtained. The amount of common information CI of intensity components of final fused colour image in the CIELAB colour space denoted as L* and source image X1 which is given as,

\[ CI = I(X1;L^*) + I(X2;L^*|X1) + .. + I(Xn;L^*|Xn-1,...,X1) \]  

The joint entropy H(X1,X2,X3,...,Xn) represents the total amount of information present in source image and which is used to represent common information. In colour image fusion distribution of colour and hues in final fused image is evaluated by angular coordinate h*ab we can evaluate colour distribution and its marginal probability density function as \( p(h_{ab}) \), which is given as,

\[ p(h_{ab}) = \int \int p(L^*,C_{ab},h_{ab}) \ dL^* dC_{ab} \]  

For the resultant colour fused image \( h_{ab} \) has its marginal pdf which is denoted as \( q(h_{ab}) \) and to identify similarity between fused colour image and the image with maximum perceivable relative information entropy distance between probability mass function \( p(h_{ab}) \) and \( q(h_{ab}) \) are analyzed which is define as,

\[ D(p_{ab}||q_{ab}) = \sum_{h} p(h_{ab}) h \log \left( \frac{p(h_{ab})}{q(h_{ab})} \right) \]  

Finally CIFM is expressed as

\[ CIFM = (IFPM, HD) \]
Mutual information along with conditional mutual information guarantees that there is no overlapping of information of same scene whereas simultaneously term HD represents divergence of hue co-ordinates, HD is given as,

\[ HD = 1 - D (p^{\ast} || q^{\ast}) \]  

(15)

VI. CONCLUSION

Presently we required compact and quality as well as more informative and integrated images in every applications such as Military, Medical analysis, Communication field etc. to get such quality image image fusion is one of solution in which we can integrate images from same or different sources in above presentation we have tried to improvise quality of fusion method by evaluating different quality metrics.

REFERENCES