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Gradient Operator Based Image Fusion

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Abstract- High dynamic contrast real world scenes cannot be often captured by a sensing device on a single shot. This can be overcome by representing these scenes as a series of differently exposed images. In this paper, a novel algorithm for fusing such images by using gradient information is proposed. From a set of under or over exposed images the proposed approach is capable of producing informative and complete image than any of the input image. A quality measure is used to find gradient changes among different exposed images. The gradient magnitude implies the pixel's exposure quality that decreases as image becomes under or over exposed. Hence it can be used to preserve details present in exposure sequence. Thus good information from each of the given images is fused together to form a resultant image whose quality is superior to any of the input images.

Keywords-High dynamic contrast, gradient, image composition.

1. INTRODUCTION

Digital cameras have a limited dynamic range, which is lower than one encounter in the real world. In high dynamic range scenes, a picture will turn out to be under or overexposed. Dynamic range refers to ratio between the brightest and darkest parts of the scene. The Dynamic Range of real-world scenes can be quite high - ratios of 100,000:1 are common in the natural world. An HDR image stores pixel values that span the whole tonal range of real-world scenes. Dynamic range of JPEG format image won't exceed 255:1, so it is considered as LDR (Low Dynamic Range).A set of image can be converted in to a single image of high dynamic range but the high dynamic range cannot be displayed using normal display device hence have to be converted to low dynamic range using tone mapping operators [1], [2]. Image fusion is a simple method that produces a low dynamic range output by using a set of input image. So to perform fusion it is necessary to have a set of input exposure where each exposure gives details about different part of the image. This paper describes an algorithm for fusing a set of multi-exposure images of a scene into an image where all scene areas appear. In this fusion is performed by finding a weighing function. Image fusion algorithms are mainly developed to obtain a pleasant and complete output when compared with the input exposures.

Broadly image fusion techniques are classified into

- Pixel level or low level
- Feature level or medium level
- Decision level or High level

Another major classification is

- Spatial domain
- Transform domain

The pixel-level method can be implemented in spatial domain [3] or in the transform domain [4], [5]. Pixel level fusion works directly on the pixels obtained while feature level fusion [6] algorithms operate on features extracted from the source images. The main requirement for such an operation is that the images have been acquired by homogeneous sensors, such that the images reproduce similar physical properties of the scene. Image fusion at pixel level amounts to integration of low-level information, in most cases physical measurements such as intensity. The feature-level algorithms typically segment the image into contiguous regions and fuse the regions together using their properties. The features used may be calculated separately from each image or they may be obtained by the simultaneous processing of all the images. Decision level fusion [8] uses the outputs of initial object detection and classification as inputs to the fusion algorithm to perform the data integration. Both feature level and decision level image fusion may result in inaccurate and incomplete transfer of information.

Several fusion algorithms starting from simple pixel based to sophisticated wavelets [5] and PCA [3] based are available. Principal Component Analysis (PCA) is a vector space transform often used to reduce multidimensional data sets to lower dimensions for analysis. The PCA image fusion method simply uses the pixel values of all source images at each pixel location, adds a weight factor to each pixel value, and takes an average of the weighted pixel values to produce the result for the fused image at the same pixel location. Discrete wavelet transform (DWT) in image fusion computes approximate and detailed wavelet coefficients which contain information of local spatial detail. The low-resolution component is then replaced by a selected band .This process is repeated for each band until all bands are transformed. A reverse wavelet transform is applied to the fused components to create the fused image. . In transform domain changing a single coefficient using transform may lead to change in all values of fused image in spatial domain.

Standard image fusion techniques that are commonly used are Brovey Transform (BT), Intensity Hue Saturation (IHS) and Principal Component Analysis (PCA) .PCA provides the basis for many commonly used image fusion techniques. Intensity-hue-saturation method is the oldest method used in image fusion that is done in RGB domain. The RGB input image is then transformed to IHS domain. Inverse IHS transform is used to convert the image to RGB domain [3]. Brovey transform is based on the chromacity transform. In the first step, the RGB input image is normalized and multiplied by the other image. The resultant image is then added to the intensity component of the RGB input image [3]. Principal component analysis-based image fusion methods are similar to IHS methods, without any limitation in the number of fused bands.

As different from previous work [8] focuses to obtain a fused image without the help of tone mapping where a weighing function is determined so that fused image can be obtained. Three quality measures contrast, saturation, well exposedness is considered to develop the weighing function. For each pixel combine information from different measures into a scalar weight map using multiplication.

Image fusion system has several advantages over single image source and resultant fused image should have higher signal to noise ratio, increased robustness and reliability in the event of sensor failure, extended parameter coverage and rendering a more complete picture of the system. The actual fusion process can take place at different levels of information representation. An ideal image fusion technique should have three essential factors they are high computational efficiency, preserving high spatial resolution and reducing colour distortion.

In this paper it is guided by a quality measure to find the weighing function. This weighing function is extracted using gradient magnitude. This is because gradient gives more significantly the information about edges. Section 2 gives over all idea of how image fusion is performed. Section 3 gives the method to extract gradients so that weighing map is obtained.

2. PROPOSED METHOD

Images from different exposures are captured and combined so that a more superior quality and informative image is obtained. The resultant image is given by

$$H(x,y) = \sum_{i=1}^{N} W^{i}(x,y) I^{i}(x,y) \quad (1)$$

where N represent number of input exposures

$I^i(x, y)$ denote intensity of pixel located at (x,y) in the i^{th} exposure

$W^i(x, y)$ denote intensity of pixel located at (x,y) in the i^{th} exposure

H denote the composite image to be generated

Compared to typical high dynamic imaging gradient based fusion is much more simple and efficient and doesnot require the computation of camera calibration curve or tone mapping operators. The final result mainly depends on the weight factor W and hence must be properly selected so that required quality is achieved. For this weight estimation a proper technique must be introduced. In this paper gradient magnitude is found to obtain the fused output.

The block level representation of fusion technique is shown in figure 1.It starts with a set of differently exposed images that are given to a quality assessment system to obtain the desired weights. These weights are then multiplied with the input set of image to obtain the fused output. This method can be applied to deal with images captured in static as well as dynamic scenes.

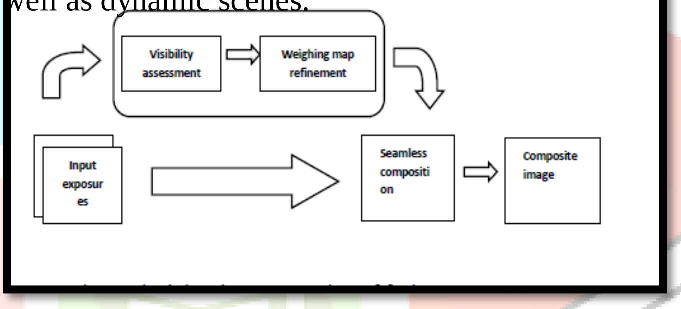


Fig.1. Block level representation of fusion system

In this paper we assume that all input sets are taken with the aid of tripod or they must be aligned using proper registration technique[9].Then the weighing map of each exposure is evaluated using gradient .In addition bilateral filtering[10] is performed to eliminate the outlier weights and also to ensure that adjacent pixels have similar weights. The standard deviation of space Gaussian is set to 5 pixels and that of range Gaussian as 5.Thus once we get the weighing map a tone mapped like HDR image can be produced using equation (1).

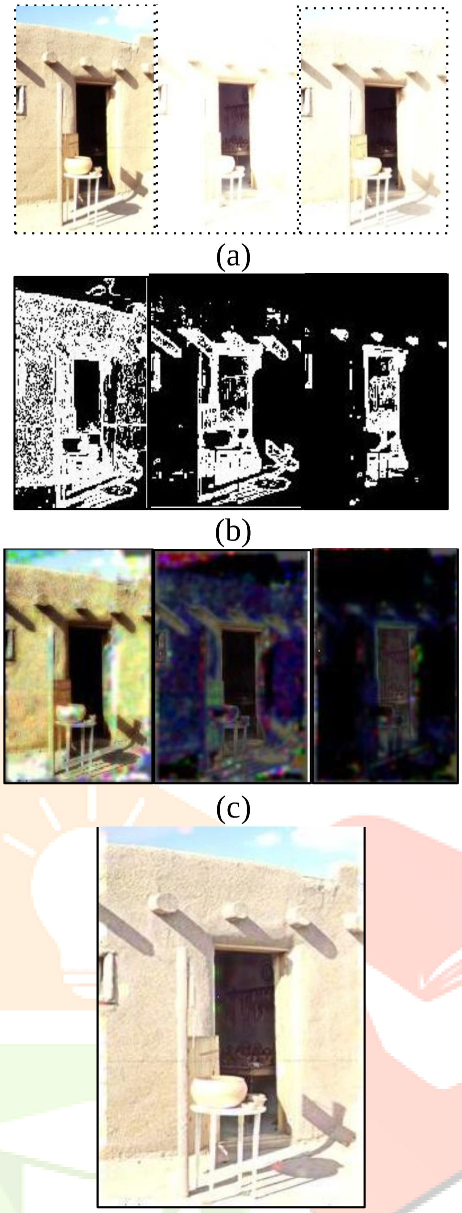


Fig 2 (a) Input exposures of static scene. (b) Gradient magnitude (c) Refined weighing map. (d) Composite image.

3 .GRADIENT BASED IMAGE QUALITY ASSESSMENT

Gradient information is extracted to generate the weighing maps for different types of scene. This is obtained by taking first derivative of 2D Gaussian filter g(x, y, σd) in x and y directions to extract the gradient information

$$I_x^i(x,y) = I^i(x,y) \otimes \frac{\partial g(x,y,\sigma_d)}{\partial x} \qquad (2)$$

$$I_y^i(x,y) = I^i(x,y) \otimes \frac{\partial g(x,y,\sigma_d)}{\partial y} \qquad (3)$$

Where $I_x^i(x,y)$ and $I_y^i(x,y)$ are the partial derivatives of image $I^i(x,y)$ along x and y directions .Standard deviation σ_d is set to two pixels. Significance of gradient magnitude is that it reflects the maximum change in pixel values. The magnitude value is given by

$$m^i(x,y) = \sqrt{\left|I_y^i(x,y)\right|^2 + \left|I_x^i(x,y)\right|^2} \qquad (4)$$

a) Visibility assessment

As in fig 2 (a), features that are visible in one exposure disappear in another because of under or over exposure. So the basic goal is to preserve all features present in each exposure and make them visible in a single image. As in fig 2(b) gradient magnitude becomes larger when a pixel gets better exposed and gradually decrease as pixel becomes under or over exposed .Thus visibility measure is given by

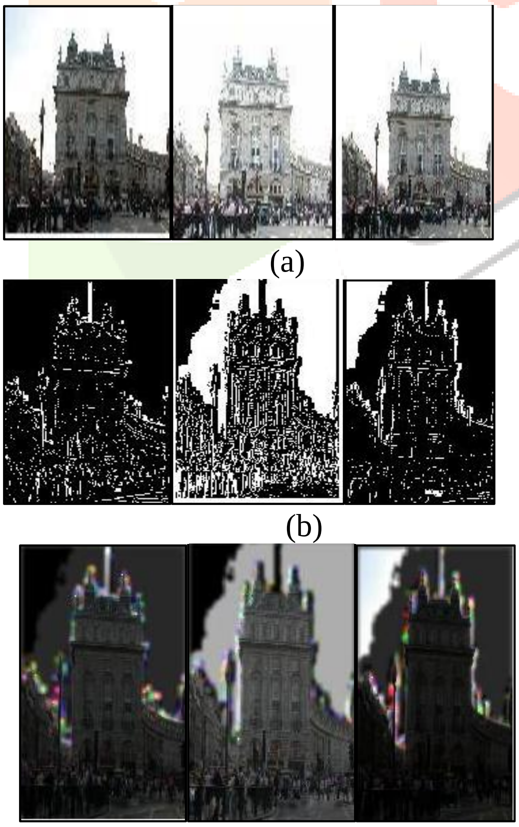
$$w^i(x,y) = \frac{m^i(x,y)}{\sum_{i=1}^{N} m^i(x,y)+\varepsilon} \quad (5)$$

Where ε is a positive value given by 10^ (-25) to avoid singularity.

Similarly in the case of dynamic scenes fig 3 (a) shows different exposures. Since gradient denotes local changes more clearly fig 3(b) shows variation in gradient magnitude.

Now to each weight bilateral filtering is performed so that distortion free image is obtained. Bilateral filtering smoothens images while preserving edges, by means of a nonlinear combination of nearby image values. If the three bands of colour images are filtered separately from one another, colours are corrupted close to image edges. In fact, different bands have different levels of contrast, and they are smoothed differently. Separate smoothing perturbs the balance of colours, and unexpected colour combinations appear. Bilateral filters, on the other hand, can operate on the three bands at once, and can be told explicitly, so to speak, which colours are similar and which are not.

Algorithm in [11] can also be extended for the fusion of MRI with CT image there by leading to a more perfect image that is informative. Medical image fusion refers to a branch of data fusion. It refers to a process of fusion itself into a synthetic medical image so as to obtain more information or become more suitable for visual sense and computer process through processing the organized information from two or more original medical image in the same scene.



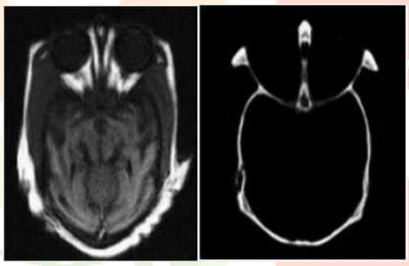
(a) (b) (c)

(d)

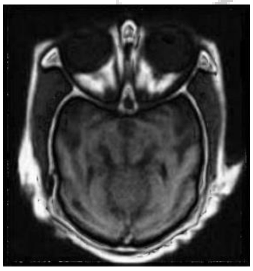
Fig 3 (a) Input three exposures of dynamic scene. (b) Gradient magnitude maps. (c) Weighting maps after refinement. (d) Composite image.

4. RESULTS AND DISCUSSION

In this, proposed method is applied to various types of images. In addition it can be used for medical image fusion which finds wide application nowadays. Also in case of gray scale or black and white images without the use of bilateral filtering pleasant output can be obtained. Another major advantage is that the proposed method relies on a single and simple parameter. Also the method can be applied to gray scale and colour images without any variation in the parameters. Only by using two inputs the algorithm provides a pleasant and superior quality output.



(a) (b)



(c)

Fig 4. Medical image fusion (a) CT image (b) MRI image (c) Fused output

5. EVALUATION PARAMETERS

It is mainly used to find the image quality which is a characteristic of an image that measures the perceived image degradation. There are several techniques and metrics that can be measured objectively and automatically. In FR image quality assessment methods, the quality of a test image is evaluated by comparing it with a reference image that is assumed to have perfect quality.

5.1Mean Square Error (MSE)

Mean square error is a measure of image quality index. The large value of mean square means that image is a poor quality.

$$MSE = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n}(A_{ij} - B_{ij})^2$$

5.2Peak Signal to Noise Ratio (PSNR)

PSNR is the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity. The PSNR value of better fused image is always high.

$$PSNR = 10 * log_{10}\frac{(Peak)^2}{MSE}$$

In our case, at pixel level, the highest possible value is 255. i.e. in a 8 bit greyscale image

5.3Structural Content (SC)

It is the ratio between the net sum of the square of the expected data and the net sum of square of the obtained data.

$$SC = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}(A_{ij})^2}{\sum_{i=1}^{m}\sum_{j=1}^{n}(B_{ij})^2}$$

5.4Normalized Cross Correlation (NCC)

Normalized Cross Correlation method is used for finding the similarities between fused image and reference image.

$$NCC = \frac{\sum_{i=1}^{m}\sum_{j=i}^{n}(A_{ij} * B_{ij})}{\sum_{i=1}^{m}\sum_{j=1}^{n}(A_{ij})^2}$$

m is the height of the image implying the number or pixel rows
n is the width of the image, implying the number of pixel columns.
A_{ij} being the pixel density values of the perfect image.
B_{ij} being the pixel density values of the fused image.

Parameter	Value
MSE	0.4292
PSNR	51.8039
SC	1
NCC	0.5725

6. CONCLUSION

Human visual system is very sensitive to gradient and gradient encodes edges and local contrast quite well. In this paper, gradient information is used to extract pixels exposure quality and hence can be utilized as a parameter for image fusion. Proposed method does not have much parameter tweaking .The major limitation is registered image used if have small variation in alignment leads to colour distortion especially at edges. In the future, efficiency of the proposed method is improved by removing the colour distortion using more sophisticated registration method. Also this fusion technique can be extended to fusion of satellite images.

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