Asian Journal of Information Technology 7 (4): 168-171, 2008
ISSN: 1682-3915

Pixel Level Multifocus Image Fusion Based on Fuzzy Logic Approach

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Abstract: Image fusion is a process of integrating information obtained from various sensors and intelligent systems. It provides a single image containing complete information. A process is designed to fuse images of the same scene that is in diverse focuses to produce an image that contains more information using fuzzy approach. The aim of this contribution is to present an alternative approach to the solution of image fusion problem. The fuzzy approach has already been implemented in various image processing applications. Experiments shows that the proposed image fusion method can have better performance.

Key words: Image fusion, multifocus, fuzzy logic

INTRODUCTION

Image fusion given by van Genderen and Pohl in (1994) is the following: combination of 2 or more different images (of the same scene) to form a new image by using a certain algorithm. Image Fusion is finding great importance in many applications such as object detection, ATR (Automatic Target Recognition), remote sensing, computer vision and robotics. Image Fusion is generally performed at 3 different levels of information representation; these are pixel level, feature level and decision level (Haroon *et al*., 2006). Fusing images at pixel level means to perform integration at a level where the pixels are least processed. Each pixel in the fused image is calculated from pixels in input/source images. Fusion at feature level first requires extraction of features from the source images (through e.g., segmentation) first; then the fusion takes place based on features that match some selection criteria. At symbol level/decision level the output from initial object detection and classification from the source image are put as input to fusion algorithm. Every image fusion algorithm is performed at one of these 3 levels or at the combination ofthese levels (Haroon *et al*., 2006). This research focuses on a framework on pixel level image fusion based on fuzzy logic approach.

A lot of image fusion approaches has been available in the literature. A simple image fusion algorithm based on wavelet transform is proposed in Wang *et al*. (2003). A multi-focus image fusion method using spatial frequency (SF) was proposed in Li *et al*. (2001). A new multi-focus image fusion algorithm, which is based on the basis of the Ratio of Blurred and Original Image Intensities was proposed in Qiguang *et al*. (2005).

Fuzzy logic has rapidly become one of the most successful of today's technologies for developing sophisticated control systems. The reason for which is very simple. This approach has already been implemented for multi image fusion for different applications. The paper (Bushra *et al*., 2007) explains the fusion algorithm based on pixel and feature level fuzzy logic to fuse multi-resolution images. In Zhang and Hu (2007) study a support vector clustering is used for fusing multi-focus images. In this study, an image fusion algorithm based on fuzzy logic is introduced.

FUZZY IMAGE PROCESSING

Fuzzy image processing is not a unique theory. It is a collection of different fuzzy approaches to image processing. Fuzzy image processing is the collection of all approaches that understand, represent and process the images, their segments and features as fuzzy sets. The representation and processing depend on the selected fuzzy technique and on the problem to be solved. Fuzzy image processing has 3 main stages: image fuzzification, modification of membership values and, if necessary, image defuzzification.

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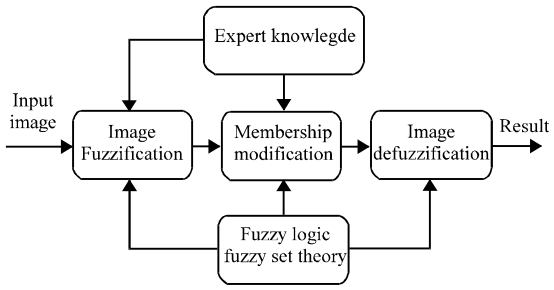

Fig. 1: The general structure of fuzzy image processing

The Fuzzification and defuzzification steps are due to the fact that we do not possess fuzzy hardware. Therefore, the coding of image data (fuzzification) and decoding of the results (defuzzification) are steps that make possible to process images with fuzzy techniques. The main power of fuzzy image processing is in the middle step (modification of membership values, Fig. 1). After the image data are transformed from gray-level plane to the membership plane (fuzzification), appropriate fuzzy techniques modify the membership values. This can be a fuzzy clustering, a fuzzy rule-based approach, a fuzzy integration approach and so on.

IMAGE FUSION BASED ON FUZZY LOGIC

In the fuzzy approach, pixel of one image is fused with the corresponding pixel value of other image. The fuzzy controlled machine is used in the fusion of multifocus images as follows. Fuzzy control, which directly uses fuzzy rules is the most important application in fuzzy theory. Using a procedure originated by Ebrahim Mamdani in the late 70s, 3 steps are taken to create a fuzzy controlled machine: Fuzzification (Using membership functions to graphically describe a situation) and rule evaluation (Application of fuzzy rules) Defuzzification (Obtaining the crisp or actual results).

Algorithm: The first step fuzzification is done as follows in both the source images:

- Arithmetic mean of $f_A(x_i) = f_A(x_1) + f_A(x_2) + f_A(x_3) \ldots f_A(x_n) = \sum f_A(x_i)$ for i = 0 to n is calculated for the source image A for each row.
- Each row of the source image is replaced by a transform function, by calculating the error function between the arithmetic mean of arithmetic mean of $f_A(x_i)$ and $f_A(x_1)$, $f(x_2)$, $f(x_3) \ldots f(x_n)$. Error function E_A is given as follows:

$$E_A = \sum f_A(x_i)/i\text{-}f_A(x_i) = f_{TA}(x_i)$$

-fuzzified image A (left focus)

- Similarly arithmetic mean of $f_B(x_i) = f_B(x_1) + f_B(x_2) + f_B(x_3) \ldots f_B(x_n) = \sum f_B(x_i)$ for i = 0 to n is calculated for the source image B for each row.
- Each row of the source image is replaced by a transform function, by calculating the error function between the arithmetic mean of arithmetic mean of $f_B(x_i)$ and $f_B(x_1) + f_B(x_2) + f_B(x_3) \ldots f_B(x_n)$. Error function E_B is given as follows $E_B = \sum f_B(x_i)\text{-}f_B(x_i) = f_{TB}(x_i)$-fuzzified image B (right focus).

- The second step Modification of memberships is done as follows, Here the rule based fuzzy approach is used for the fusion.

- If $f_{TA}(x_i) = f_{TB}(x_i)$ then $F_f(x_i) = 0$
- If $f_{TA}(x_i) > f_{TB}(x_i)$ then $F_f(x_i) = 1$
- If $f_{TA}(x_i) < f_{TB}(x_i)$ then $F_f(x_i) = -1$

- The third step defuzzification is done as follows:

- If $F_f(x_i) = 0$ then $F_f(x_i) = f_{TA}(x_i)$ or $f_{TB}(x_i)$
- If $F_f(x_i) = 1$ then $F_f(x_i) = f_{TA}(x_i)$
- If $F_f(x_i) = -1$ then $F_f(x_i) = f_{TB}(x_i)$

Flowchart: The general framework of the proposed algorithm can be shown with the help of flowchart. The flowchart explains how the source images are fuzzified and the memberships are modified and later dufuzzified to produce the fused result.

RESULTS AND DISCUSSION

Then the $F_f(x_i)$ is the fused image and the experimental results are as follows. The resultant image is given in the Fig. 2a. For the purpose of comparison the images are fused using pixel level maximum and minimum method and is given in Fig. 2b. The spatial frequency is calculated for the fused images and is tabulated in Table 1. The left and right focus images are the source images and the fused images are given in Fig. 3-6.

From the above results, it is clear that the fused images using fuzzy approach yields better results than the other one. It is also proved by the quantitative analysis. In quantitative analysis of images, there is no universally accepted measure to estimate the quality of the fused images. Here the spatial frequency, which measures the overall activity level of an image, is used to estimate the quality of fused image shown is Table 1.

From the values of the spatial frequency, it is found that it is high in fuzzy approach. It is also tested with the various image samples.

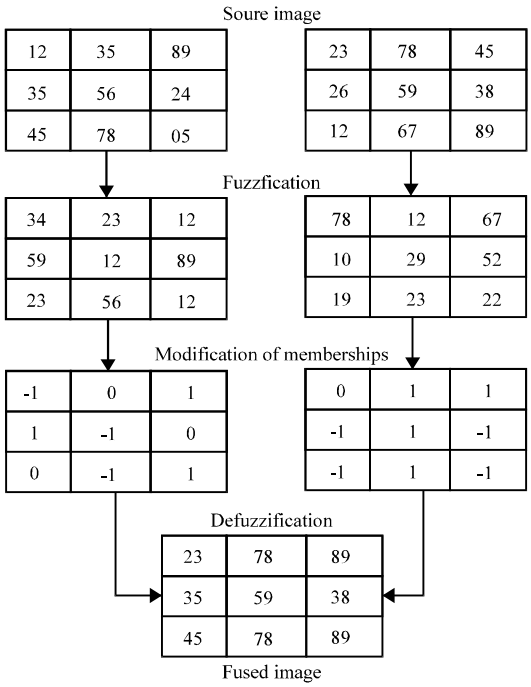

Fig. 2: Flowchart for proposed algorithm

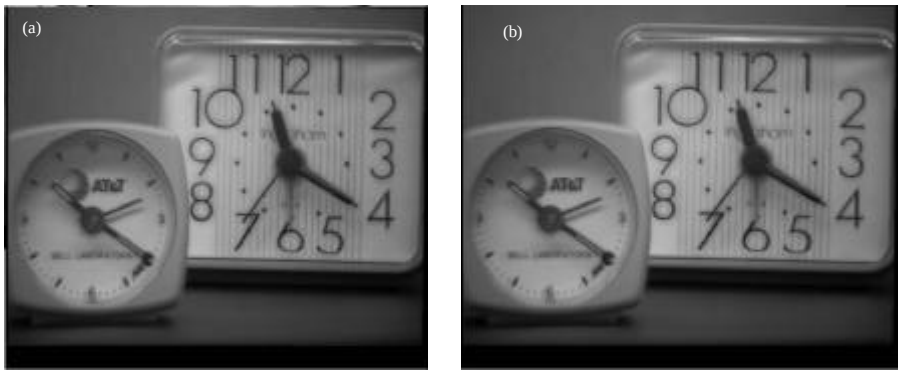

Fig. 3: (a) Fused image-fuzzy approach (b) Fused image-maximum and minimum

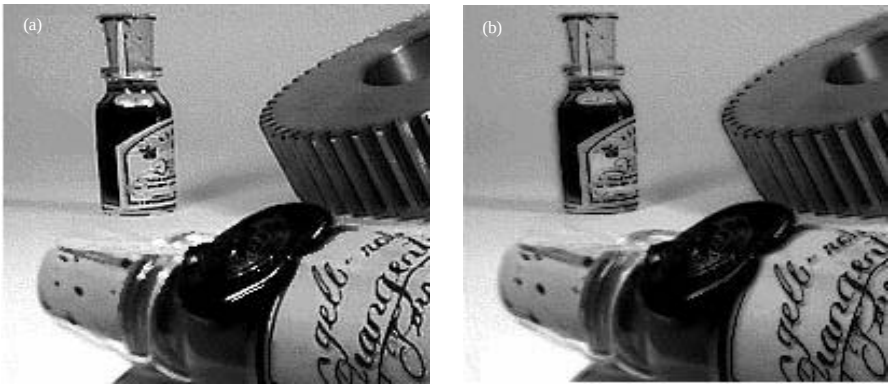

Fig. 4: (a) Fused image-fuzzy approach (b) Fused image-maximum and minimum

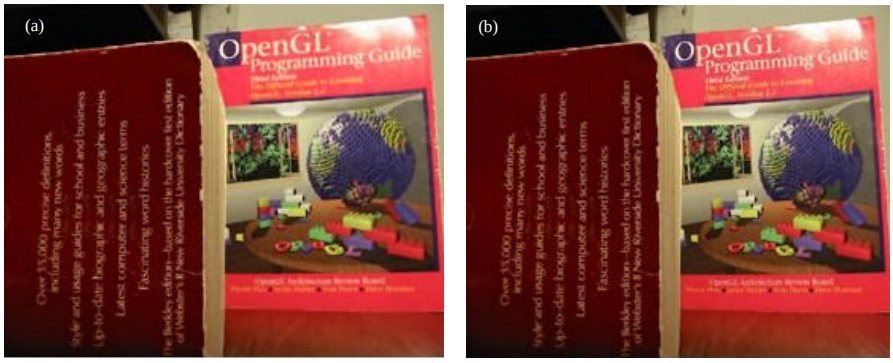

Fig. 5: (a) Fused image-fuzzy approach (b) Fused image-maximum and minimum

Fig. 6: (a) Fused image-fuzzy approach (b) Fused image-maximum and minimum

Table 1: The spatial frequency is calculated for the fused images

Images	Fuzzy approach	Maximum and minimum method
Clock image	2.36E+11	2.26E+11
Bottle image	6.66E+12	3.04E+12
Book image	2.13E+12	2.06E+12
Old man image	2.04E+12	1.82E+12

CONCLUSION

An image fusion algorithm for fusing multi-focus images based on fuzzy logic approach is proposed. The experiments shows that the algorithm using the fuzzy technique performs better than the pixel level maximum method. The quality of the fused images is also improved using the fuzzy technique. Future work includes the computationally fast image fusion algorithm, which gives better performance than the above approach.

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