GUI FOR IMAGE FUSION IN MEDICAL IMAGES OF BRAIN

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Abstract

In recent years of great technological development, medical diagnostic and treatment require great precision from various medical imaging methods such as Magnetic Resonance Imaging (MRI), Computed Tomography (CT), Single-photon emission computed tomography (SPECT) etc. These imaging methods often give unique information. Therefore, a post imaging method known as image fusion is often applied. This method synthesizes information from two or more images into one single image that carries all the relevant data. In this paper we propose a program and simple specialized Graphical User Interface (GUI), which is developed in MATLAB-environment. Different wavelet-based image fusion methods applied on MRI and SPECT medical images of brain can be analyzed on the base of different wavelet decompositions. The proposed GUI can be applied in Computer Aided Diagnostics for real images attempt to make medical diagnosis more precise. The presented GUI is suitable also to engineering education for studying of medical image fusion.

1. INTRODUCTION

Magnetic Resonance Imaging (MRI) is a medical imaging modality that can obtain images of the soft tissue and the non-bony parts such as blood vessels, ligament tears and many more. Talking about imaging of the brain, this medical imaging method shows the brain structure. The obtained images are usually good quality.

On the other hand, the Single-Photon Emission Computerized Tomography (SPECT) is a medical imaging modality that is used to present the blood circulation on different tissues and organs. When imaging the brain, the cerebral blood flow is measured and is used for diagnostic of brain diseases such as dementia. However, often these image sequences are difficult to interpret, because they could be blurred.

The growing appeal on using image fusion in the field of medicine can be observed from the large number of scientific papers published since 2000 on the topic [1, 2, 3, 4]. In publication [5] an image fusion GUI is developed, whereas the same techniques are used as the GUI in this article, but the input images are MRI and CT. Compared to the developed GUI in this paper, the GUI in [5] is used only for analysing the general combinations of wavelets and fusion rules that obtain the highest result. However, in our investigation, not only the fusion rules are taken into account when analysing the result, but also the different wavelet functions from different wavelet families and their decompositions levels, making this study more comprehensive.

The rest of the paper is structured as follows. In Section 2, the briefly theoretical part is given. In Section 3, the GUI for wavelet-based medical image fusion is presented. Section 4 describes tasks carried out from the main program. Some experimental results are presented in Section 5. Concluding remarks are given in Section 6.

2. THEORETICAL PART

The wavelet image fusion is done in three stages: first is the decomposition of the source images at different levels using tensors; than the combination of the obtained wavelet coefficients is performed. The approaches used when combining these coefficients are called Fusion rules; an inverse wavelet transform is applied to obtain the fused image. A graphic of wavelet-based image fusion is shown on Figure 1.

On Figure 1, it is denoted that the two input medical images from different medical modalities are image A and image B. The first step of the algorithm is to decompose each source image with the help of wavelet transform into wavelet coefficients. In this case, the multidimensional wavelets can be presented as a tensor product of separable basis functions, defined in every dimension. Knowing this, the wavelet decomposition can be defined as a set of wavelet coefficients, where the scaling wavelet function $\varphi(x,y)$ can be presented in Eq.1 as the tensor product [6]:

$$LL = \varphi(x, y) = \varphi(x).\varphi(y) \quad (1)$$

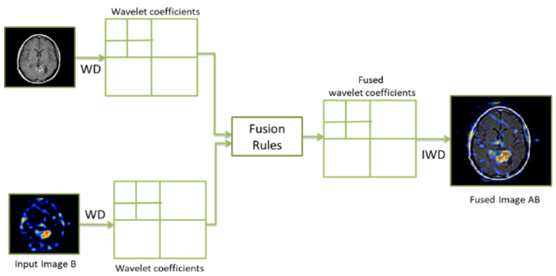

Figure 1. Wavelet Image Fusion scheme

Than in Eq.2 the wavelet functions $\Psi(x,y)$ are as follows

$$LH = \Psi_{LH}(x,y) = \varphi(x).\Psi(y),$$
$$HL = \Psi_{HL}(x,y) = \Psi(x).\varphi(y), \quad (2)$$
$$HH = \Psi_{HH}(x,y) = \Psi(x).\Psi(y),$$

where L represents the usage of a low pass filter and H – the usage of a high pass filter. The decomposition stage transforms the image into approximate and informative coefficients using Tensor Wavelet Decomposition (TWD) at some specific level. Therefore one 2-dimensional wavelet function LL is obtained, representing the low-frequency band. This image contains maximum energy and information. Obtained are also three more 2-D wavelet functions (LH, HL and HH), describing the high frequency bands. These images are called detailed or informative, thus they describe different types of image details. The LH (Low-High) subimage represents information about the horizontal edges, HL (High-Low) subimage contains details about the vertical edges and the HH subimage describes the diagonal details. For obtaining a next level of decomposition, the decomposition stage is carried out, but this time the approximation coefficients (LL) from the previous level are used.

After both images are decomposed and their wavelet coefficients are obtained, the second stage occurs. This is the stage where the obtained wavelet coefficients from images A and B are fused. This means that the approximation and detail coefficients from both images are combined together obeying *fusion rules* in order to form one fused image. The fusion rules used, are from the category of spatial fusion techniques. They present a way of fusing medical images without using significant part of the resources of the computer [7]. The simple Fusion techniques fuse separately the detail and approximation coefficients. Three main techniques are presented in the Image Fusion GUI: Average selection scheme, Minimum selection scheme and Maximum selection scheme and Adaptive scheme. The third step of developing fused image is to perform an inverse wavelet transform that makes it possible to visualize the fused image AB. This image contains the synthesized coefficients from both images.

3. GUI FOR IMAGE FUSION

For solving the task of image fusion, a specialized Graphical User Interface (GUI) is developed in MATLAB-environment. The interface will enable the user to perform wavelet image fusion on two medical images, while giving the user an opportunity to test different combinations of wavelet decomposition methods and fusion rules.

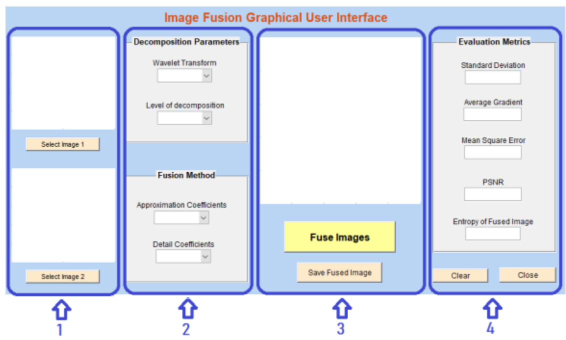

Figure 2. GUI for wavelet image fusion

The initial state of the GUI can be seen on Figure 2, where 4 panels can be defined. Panel one gives the user the opportunity to select the two input images. When button "Select Image 1" is clicked-on, the user can navigate among the folders in the workspace and choose image, after that the chosen image is displayed on the axes above the button. Pushing the button "Select Image 2" give the user the opportunity to select the second image in the same manner. This action is demonstrated in Figure 3.

If the two selected images do not have the same size, image fusion is unapplicable and the GUI shows an error window explaining the problem to the user. This is demonstrated on Figure 4.

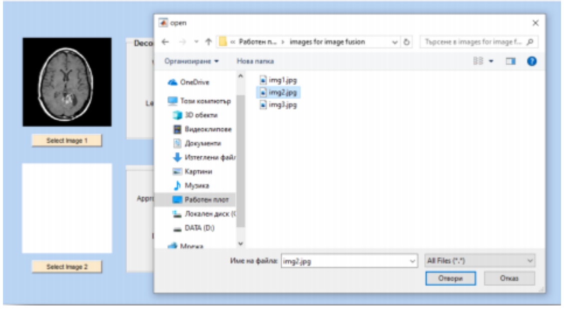

Figure 3. Image Selection

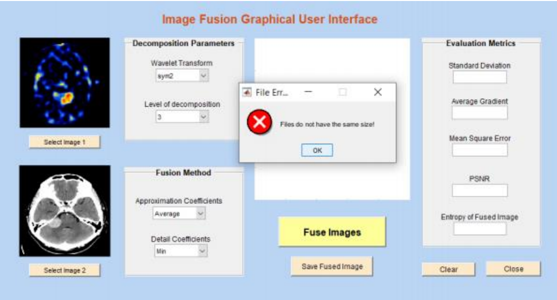

Figure 4. Error for uneven size of input images

Panel two enables the user to test out different combinations of image decomposition and image fusion rules. The upper part of this panel is responsible for the selection of the Decomposition Parameters. The user can select one of the predefined wavelet transforms (haar, db2, db20, sym2, sym3, coif1, dmey) using the drop-down menus [7]. For selected wavelet function we obtain very good results for image fusion. The available options for wavelet transforms are not random. Taken in account the study [8], the same wavelet transforms are presented, since they have achieved the best results.

The selection of a different level of decomposition from 1 to 5 is also possible with the help of a drop-down menu. We obtain bad quality of the fused images for decomposition levels higher than 5. The lower part of the second panel is for the selection of the image fusion rules. Thus, the main fusion method synthesizes separately the Low- and the High-Frequency subbands, there are two drop-down menus in this subpanel: one for fusing the approximation, and the other is for choosing the fusion rule that the functions of the detail coefficients should be selected. The selection of the fusion rule for the detail coefficients is demonstrated at Figure 5.

Panel 3 have two important buttons. The button *Fuse Images* applies all of the user preferences and fuses the input images. The user can also press the button *Save Fused Image* and can save the resulting image onto his workspace. The result of pressing the button *Fuse Images* can be seen on Figure 6. The resulting image is shown on the axes above the buttons.

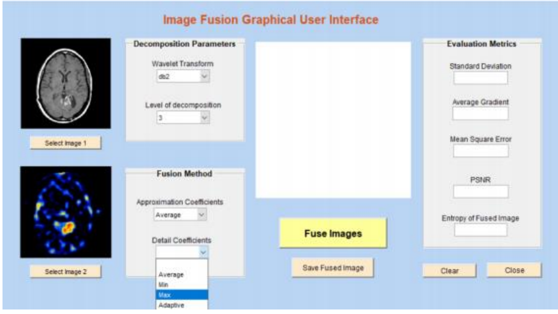

Figure 5. Parameter selection

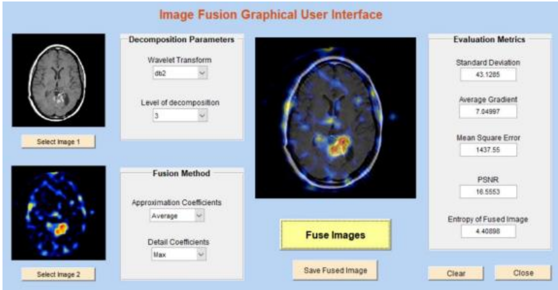

Figure 6. Fused image

Right after the fusion happens on panel 4 the accessed metrics are calculated and shown. This enables the user to make quick and precise judgment of the fusion – is it successful or not. The Evaluation metrics shown are: Standard Deviation, Average Gradient, Mean Square Error, PSNR and Entropy of the fused image. For the better results of the MRI/SPECT fusion, the Entropy should be minimal, but PSNR should be as higher as possible Panel 4 contains two additional buttons – *Clear* and *Close*. The *Clear* button deletes all the preselected preferences and returns the GUI to its initial state, where the user can perform the image fusion again. The *Close* button simply closes the GUI and exits from the application.

4. TASKS, CARRIED OUT BY THE MAIN PROGRAM

The main algorithm working behind is shown on Figure 7.

The GUI is developed with the help of the graphic redactor GUIDE. After the computation of the GUI, two files are present: one „fig" file containing a figure that presents information concerning the outlook of the user interface and a ".m" file containing the main program. Within this program there are functions that define the work of each programmable component from the figure.

Each graphical component from the GUI is being handled as an object. Each object refers to a handle (pointer) and has a list of properties that can be altered through programming if needed. Objects properties can be changed only if the object is defined by its handle or other type of reference. When initializing the GUI, each graphical component is registered in the MATLAB-environment and it is provided with a callback function, that can change the state and properties of the object. The formed callback functions are present in the main program and can be altered.

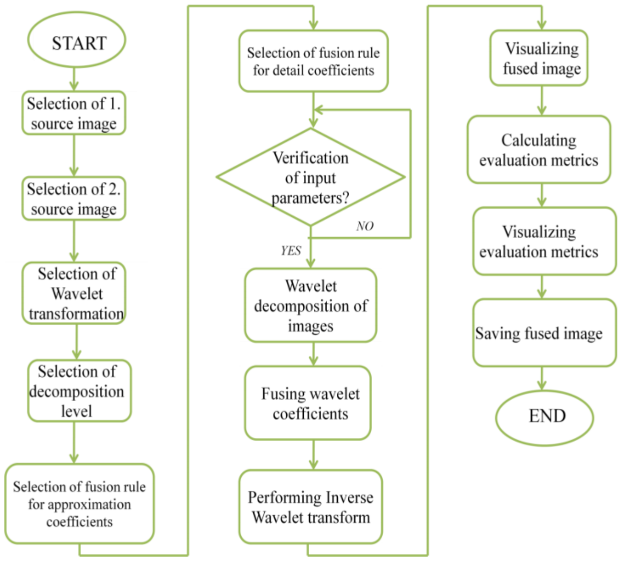

Figure 7. Block scheme of the program

Each callback function has the form: *Function Callback (hObject, eventdata, handles), where hObject* is a pointer that associates this specific function with its exact graphical component, providing the ability to change the properties of the graphical component from the main program. *Handles* is a pointer that can enable the saving and retrieval of information or other manipulations. The *eventdata* is a data structure that is reserved and will be used automatically from MATLAB in future versions.

In the development of this particular GUI the function *setappdata (obj,name,val)* stores the contents of „*val*". To identify the data for later retrieval, *obj* identifies the graphic object and name identifies the name, where the function *val=getappdata (obj, name)* retrieves data stored using the *setappdata* function. To retrieve the desired data – obj and name are used as identifications.

5. EXPERIMENTS AND RESULTS

Our investigations for application of the different methods of the medical image fusion and the multimodal imaging of the human brain have shown that the combination of an average fusion rule for the approximation coefficients and the detail coefficients gives better results.

Some experimental results can be seen on Table 1. It should be taken in account that Entropy of the fused image value should be minimal, since this indicates that the fused image is carrying greater information. and in the meantime, the Peak-Signal-to-Noise-Ratio (PSNR) value should be high, since larger values are associated with less noise in the fused image. It should be denoted that since we are working with medical images, the analysis of the evaluation metrics is not enough and a visual analysis of the fused image is also needed.

Table 1. Results for accessing fusion rules

Fusion Methods		Evaluation metrics		
Approxim.Coeff.	**Detail. Coeff.**	**MSE**	**PSNR**	**Entropy *imf***
Average	**Average**	**1.4016**	**16.6646**	**4.2764**
	Min	1.4178	16.6146	4.7628
	Max	1.4187	16.6118	4.7452
	Adaptive	1.5607	16.3121	4.9570
Min	**Average**	2.3382	15.8487	3.3094
	Min	2.3412	15.8170	3.4269
	Max	2.3424	15.8263	3.4535
	Adaptive	2.2734	15.2922	3.7806
Max	**Average**	2.4833	15.4966	5.7880
	Min	2.5020	15.4415	5.7858
	Max	2.5012	15.4339	5.7888
	Adaptive	2.6856	15.6521	5.6790

Figure 8 represents the image correspondent to this exact fusion method.

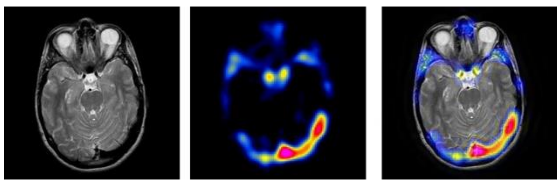

Figure 8. Successful image fusion of brain

Note that all the experiments are made with a *dmey* wavelet function at a 3rd level of decomposition. More detailed information about the results in regard to the selection of a suitable wavelet function can be found in [7].

6. CONCLUSION

In this paper we present a program with GUI for image fusion in MRI and SPECT images of the brain. The developed program provides good opportunities on the task of image fusion, whereas the GUI enables the user to interactively select the input images and all the needed setting for the execution of image fusion.

The program performs the task easily and calculates the evaluation metrics fast. This enables the user to analyse more data easily on the topic of medical image fusion. Note that images from SPECT could be blurred, therefore in a future work a pre-processing panel will be included in order to reduce the problems concerning the images from SPECT medical modality. The proposed GUI can help for making medical diagnosis more precise. The presented GUI is suitable also to engineering education for studying the process of medical image fusion.

7. ACKNOWLEDGMENTS

This work was supported by the National Science Fund at the Ministry of Education and Science, Republic of Bulgaria, within the project KP-06-H27/16 „Development of Efficient Methods and Algorithms for Tensor-based Processing and Analysis of Multidimensional Images with Application in Interdisciplinary Areas "

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