Fusion of Harmonic Ultrasounds Images and Standards Ultrasounds Images Modeled with Human Visual System

Feten Besbes
Electrical Engineering
National School of Engineers of Sfax
REGIM laboratory
Sfax, Tunisia
Feten.besbes@yahoo.fr

Hatem Besbes
Biophysics and Medical Imaging
Faculty of Medicine of Tunis
Biophysics and Medical Imaging Laboratory
Tunis, Tunisia
besbesh@gmail.com

Chokri ben Amar
Electrical Engineering
National School of Engineers of Sfax
REGIM laboratory
Sfax, Tunisia
chokri.benamar@ieee.org

Abstract*—Classical fusion techniques of medical images don't take into consideration the subjective evaluations of doctors, although, perception represents a reliable and efficient evaluation criterion. The human visual system HVS is mathematically represented by the Contrast Sensitivity function (CSF) which defines the rates of visual contrast sensitivity through the variation of spatial frequencies. Thus, we propose new techniques in image fusion based on wavelet transformation of standard ultrasounds image and harmonic ultrasound, by modeling the CSF in the fusion process.

Keywords*—fusion; Human Visual System (HVS); Contrast Sensitivity Function (CSF); standard ultrasounds image; harmonic ultrasounds image.

I. INTRODUCTION

The amount of medical information has become very important following the rapid evolution of technologies and medical instrumentation and the increasing number of sources and techniques for data acquisition [1], which explain the increasing needs for fusion processing of information to extract valuable knowledge and make better decisions.

So far, multiple effective techniques have been proposed for images fusion, notably in medical image field. Image fusion Techniques can be classified into three categories:

- Techniques based on spatial domains algorithms.
- Techniques based on multi-resolution decomposition algorithms.
- Techniques based on probabilistic algorithms

These techniques represent an evolution in the field of image fusion but they do not take into account the criterion of subjectivity. This criterion is linked to visual assessment, which is a reliable criterion and represents the decisive factor for the analysis and the medical diagnosis.

Watanabe et al. have successfully discovered a mathematical relation between the rate of visual contrast sensitivity and spatial frequencies. [2] This mathematical relation was represented by the Contrast Sensitivity Function (CSF).

The CSF has been well exploited in the optimization of treatment methods, analysis, data compression, etc.

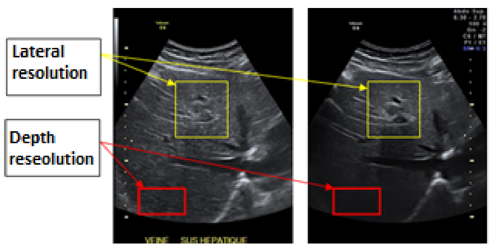
This is the reason why we think about modeling the CSF in the process of medical images fusion.

The focus of the present paper is the way we integrate the characteristics of the HVS in the process of medical image fusion based on technique of wavelets transformation. We took as case study the fusion of standard ultrasounds image and harmonic ultrasound image.

II. FUSION OF STANDARD ULTRASOUNDS IMAGE AND HARMONIC IMAGE MODELED BY HVS

Analyses of ultrasound images allow the clinician to identify the existence of pathologies in an anatomical target in addition to other tumor marker assays, function tests...

The acquisition with ultrasound modality can be made by several techniques mainly the standard acquisition (B-mode) and the harmonic acquisition. These two techniques provide two types of images. The image produced by standard acquisition is not only characterized by a good resolution in depth but also by a low lateral resolution and low contrast compared to the image produced by harmonic technique. These differences can be complementary and can provide good results after fusion. In addition, the quality of reproduced ultrasound image from the fusion can be improved by taking into consideration the human abilities. (Fig.1)



(a) (b)

Figure 1. Ultrasound images of the hepatic vein (a): standard ultrasound image, (b): Harmonic ultrasound image

A. Interaction between HVS model and fusion process

The psychophysics researches show that the HVS system function is based on a set of perceptual channels spread over the spectrum of spatial frequency [2]. This can be adapted with wavelets, which explains our choice to apply the HVS model with the fusion based on the technique wavelet transformation. [2]

The core idea is to calculate a mask from the CSF function adapted to wavelet coefficients. This mask is applied on matrix of wavelet coefficient produced from the wavelet transformation of each ultrasounds image before fusion. The same mask is applied on the wavelet coefficient matrix resulted from the fusion.

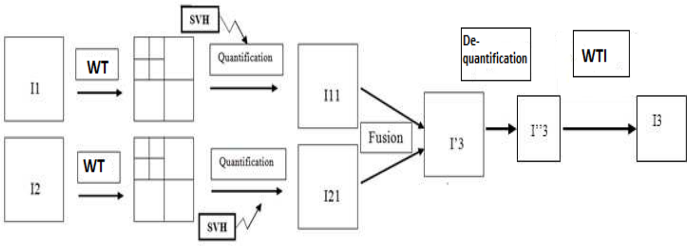


Figure 2. : HVS model in fusion process

B. Approach of fusion modeled with HVS

Our approach consists in developing quantification adapted to HVS system through the CSF function. The quantification factors represent the average sensitivity of the frequency sub-bands of the HVS system corresponding to each wavelet sub-band [2].

The frequency bands are defined by analogy to the wavelet decomposition. While, the coefficients h_{csf} are equal to the average of the CSF value of the spatial frequencies of each sub-band.

Thereafter, the coefficients are normalized, so that the minimum value of h_{csf} be equal to 1. The h_{csf} coefficients are calculated according to the following equation "(1)":

$$h_{csf}(\lambda)=\int_i^j csf(f)$$

Where, i, j are the limits of each sub-band csf(f) of contrast sensitivity function and f is the spatial frequency in cycle per degree.

We note by $\hat{h}_{csf}$ the normalized quantification coefficient of $h_{csf}(f)$. C and $\hat{C}_{svh}$ are respectively original and quantified coefficients of wavelet. Relation between C and $\hat{C}_{svh}$ is defined by the following formula "(2)".

$$\hat{C}_{svh} = C.\hat{h}_{csf} \tag{2}$$

We notice that the visual contrast sensitivity reaches its maximum between sub-bands 4 and 5 for 5 iteration of wavelet decomposition. The following figures 2, 3 and 4 show how to apply the fusion with HVS.

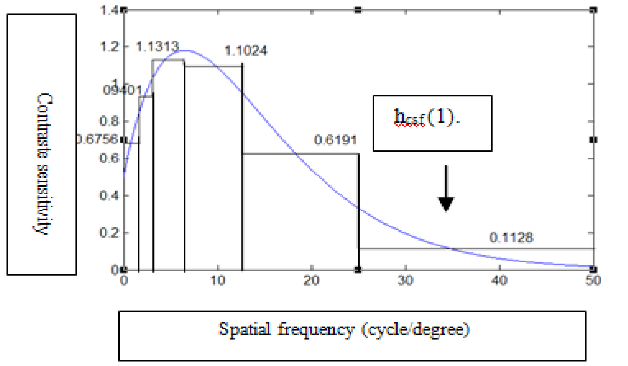


Figure 3. calculate the mean value h_{csf} of each band of the curve CSF

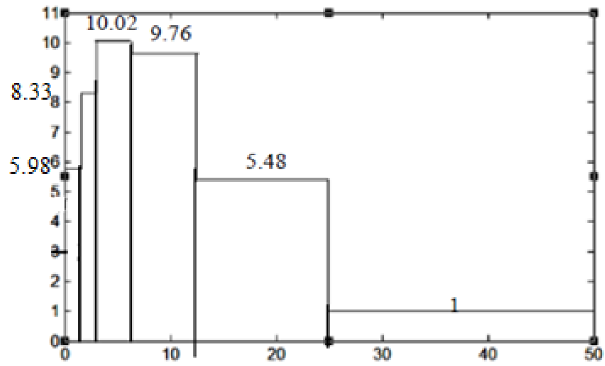


Figure 4. : Normalized $\hat{h}_{csf}$coefficient

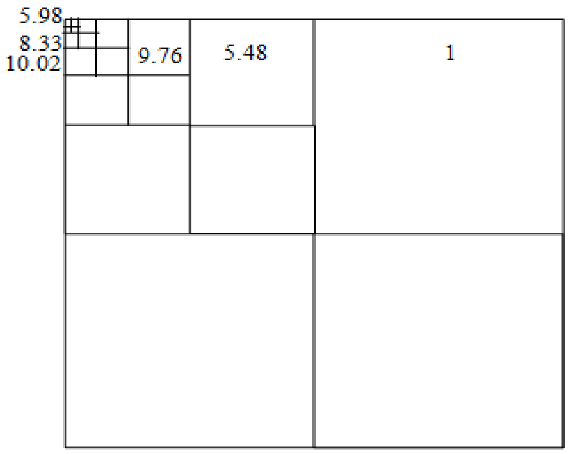


Figure 5. match between wavelet coefficients and the $\hat{h}_{csf}$ coefficient of 7 increase coefficient

III. RESULTS, MEASURES AND PERFORMANCES

The images acquired are the liver, pancreas, right kidney, bladder, lower vena cava and hepatic vein using the Philips HD7 XE machine and General Electric Voluson E6 machine. (TabI, II)

TABLE I. COUPLE OF STANDARD AND HARMONIC ULTRASOUNDS IMAGES

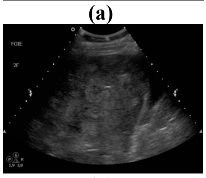
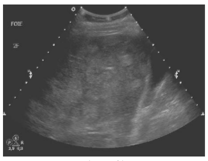
Images	Description
 (a)  (b)	(C1) Ultrasound images of liver. They have multiple hepatic masses. (a) standard ultrasound image (b) harmonic ultrasound image
 (c)  (d)	(C2)Fusion of images of pancreas with and without HVS (c) standard ultrasound image (d) harmonic ultrasound image

TABLE II. RESULTS OF FUSION BY HVS AND WITHOUT HVS OF STANDARD AND HARMONIC IMAGES.

Image Couple	Fusion WT	Fusion WT + HVS
C1(a,b): fusion of hepatic images without HVS (IF1) and with HVS (IFS1)	 (IF1)	 (IFS1)
C2(c,d) :fusion of images of pancreas without HVS (IF1) and with HVS (IFS1)	 **(IF2)**	 **(IFS2)**

A. Objective evaluation

The evaluation results of fusion can be performed by several criteria for the objective assessment such as MSE (Mean Square Error), NMSE (Normalized Mean Square Error), wPSNR (Weighted PSNR). The computed performances are made for the whole image and for a region of interest.

1) Results of the Objective evaluation of the whole image

We made objective evaluation for the whole image obtained after the SVH fusion to show that the application of mask obtained from CSF function did not affect the image details compared to the image resulted from the fusion without the CSF mask. (Tab.III, Tab.IV and Tab.V)

TABLE III. CALCULATION OF MSE BETWEEN THE ORIGINAL IMAGES AND THE FUSED IMAGES WITH HVS AND WITHOUT HVS .

MSE	Original			
	Liver		*Pancreas*	
	a	*b*	*c*	*d*
Fusion TOD (IFi)	129.89	136.80	483.78	920.26
Fusion TOD + HVS (IFSi)	129.78	136.65	483.75	920.22

TABLE IV. CALCULATION OF NMSE THE BETWEEN ORIGINAL IMAGES AND THE FUSED IMAGES WITH HVS AND WITHOUT HVS.

NMSE	Original			
	Liver		*Pancreas*	
	a	*b*	*c*	*d*
Fusion TOD (IFi)	2.1796	2.4526	5.3579	11.865
Fusion TOD +HVS(IFSi)	2.1777	2.4499	5.3576	11.864

TABLE V. CALCULATION OF PSNR BETWEEN THE ORIGINAL IMAGES AND THE FUSED IMAGES WITH HVS AND WITHOUT HVS.

PSNR	Original			
	Liver		*Pancreas*	
	a	*b*	*c*	*d*
Fusion TOD (IFi)	25.5933	25.4479	21.1815	18.3197
FusionTOD+HVS(IFSi)	25.5970	25.4528	21.1818	18.3198

1) Results of the Objective evaluation of the ROI

The objective evaluation of the ROI shows clearly that the quality of the image resulted from the fusion with the application of mask CSF is better than the quality of the image resulted from the classic technique of fusion.(TabVI)

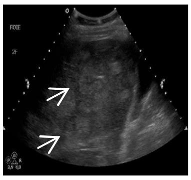
TABLE VI. CALCULATION OF PSNR BETWEEN THE ROI OF THE ORIGINAL IMAGES AND THE ROI OF THE FUSED IMAGES WITH HVS AND WITHOUT HVS.

PSNR	Original			
	Liver		*Pancreas*	
	a	*b*	*c*	*d*
Fusion TOD (IFi)	20.0290	19.1354	12.8036	13.3830
FusionTOD+HVS(IFSi)	22.7041	22.5709	13.5695	14.0635

B. Subjective evaluation

This type of evaluation is rather concerned with details of clinical interest. The subjective Evaluation has been carried out in collaboration with Dr. Hinda Ketata, hostpital assistant doctor. (Tab.VI)

TABLE VIII. SUBJECTIVE EVALUATION BY DOCTOR HINDA KETATA

Fusion WT	**Fusion WT+SVH**	**Comment**
		It represent and ultrasound image of liver. In the picture with SVH hyper echoic liver masses can be seen in relation to the image without HVS. The limits of the liver's injuries are sharper in the picture with HVS than in the image without HVS. (white arrows)
		It represents an axial section through the liver and pancreas. The contours of the pancreas and the boundaries between the pancreas and liver are more visible in the image fused with HVS than in the image fused without HVS.

C. Interpretation of results

The objective measurements of the region of interest show us clearly the improvement of the quality of the image resulted from the fusion of ultrasounds images with the application of CSF mask compared to the quality of the classic fusion approach.

This improvement does not hit the information of the entire image, us shown by the objective measurements of the whole image.

For the subjective comparison performed by a medical practitioner showed a marked improvement using the HVS mask. Because for the subjective evaluation, we focus on very specific areas of interest in the image, as proven by the measures applied on the region of interest

CONCLUSION

This paper presents a new technique in medical image fusion that takes into consideration the human visual system caracteristics. In fact, it consists in modulating the CSF function in the process of medical fusion image with wavelet transformation. The basic idea is to calculate for each sub-band the coefficients proportional to the sensitivity of the HVS system to spatial frequencies. The determination of coefficient consists in calculating the average value defined by the subbands and CSF curve portions. The mask is applied to the obtained coefficients (resulting from the wavelet decomposition) in a manner which is consistent with the change of the sensitivity of the HVS system to spatial frequencies. The increase of the wavelet coefficients by those of the CSF causes spatial frequencies less perceptible by visual system to apear and preserves good spatial frequencies that are already visible by the visual system.

The effeciency of the proposed algorithme is proven by the evaluation of technique applied on a set of ultrasounds image fused by the standard technique of fusion with wavelet transformation and the same set of images fusied by our proposed technique of fusion with wavelet transformation with application of CSF mask. The proposed algorithm ensure the preservation of the image information, as shown in the objective evaluation part, with improvement of quality, as shown in the subjective evaluation part in comparison with the standard technique.

REFERENCES

[1] G. Bhatnagar , Q.M. Jonathan Wua, Z. Liu. "Human visual system inspired multi-modal medical image fusion framework", Expert Systems with Applications, Elsivier, 2013, ,1708–1720,

[2] I. Khaled. Exploitation du système psychovisuel humain pour la compression des images. Mémoire de DEA. Sfax: Ecole Nationale d'Ingénieur de Sfax, 2003.

[3] I.Bloch, H.Maitre. «Fusion en traitement d'images : spécificités et approches numériques.» 10 Mai 2002. http://www.techniques-ingenieur.fr. Article.

[4] A.Florent. Fusion d'image fondé sur la modélisation du SVH et sur la transformée mojette. Thèse de doctorat. Nante: École polytechnique de l'université de Nantes, 2002.

[5] B.Zhang, C.Zhang, J.Wu, H.Liu. A medical image fusion method based on energy classification of BEMD components. 2014. Optik 125, Elsivier, 146-153.

[6] J.Stoll. Ultrasound fusion imaging. 2012. Perspective in Medicine. Elsivier. 80-81