Technical report associated with the paper "Fusion of Magnetic Resonance and Ultrasound Images for Endometriosis Detection"

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A. *The role of hyperparameters*

This section explains the role of the different hyperparameters of an algorithm associated with the paper "Fusion of Magnetic Resonance and Ultrasound Images for Endometriosis Detection". In particular the performance of this algorithm in terms of CNR and slope is analyzed for several hyperparameter combinations. More precisely, the proposed algorithm requires to adjust 4 hyperparameters

- τ_1: this hyperparameter balances the weight between the MRI data fidelity term and the total variation regularization. Considering that TV promotes a piece-wise constant fused image, increasing τ_1 decreases the resolution of the fused image, which is measured using slope interfaces (see Fig. 7 in the paper). This remark has been highlighted in Fig. 1 below: when τ_1 exceeds 5.10^{-2}, the slope 2 interface starts to decrease and the fused image is blurred.
- τ_3: this hyperparameter has the same effect as τ_1 on the fused image.
- τ_4: this hyperparameter is essential in the proposed fusion algorithm. The choice of τ_4 is based on the quality of MRI and US images. Different values of τ_4 provide different fusion results. When τ_4 has a low value, the fused image is close to the high-resolution MRI image. Conversely, when τ_4 has a high value, the fused image is a despeckled US image as shown in Fig. 2.
- τ_2: this hyperparameter has the same effect as τ_4 on the fused image.

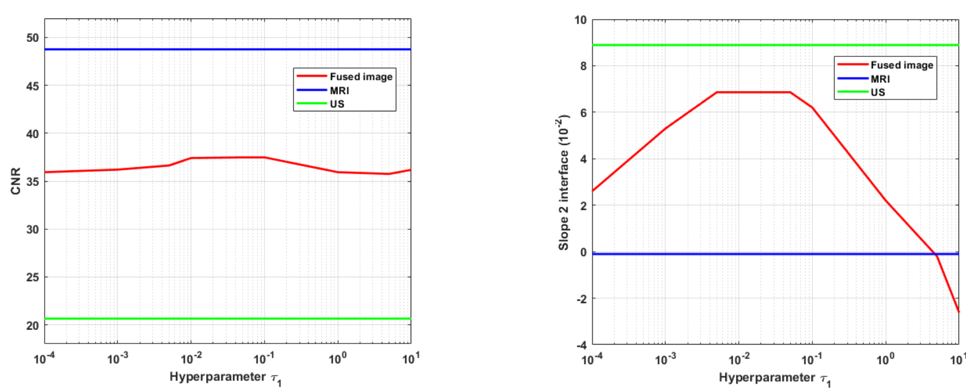

Fig. 1: Influence of the hyperparameter τ_4 on the fused image. (a) shows the CNR evolution whereas (b) shows the evolution of the interface 2 slope.

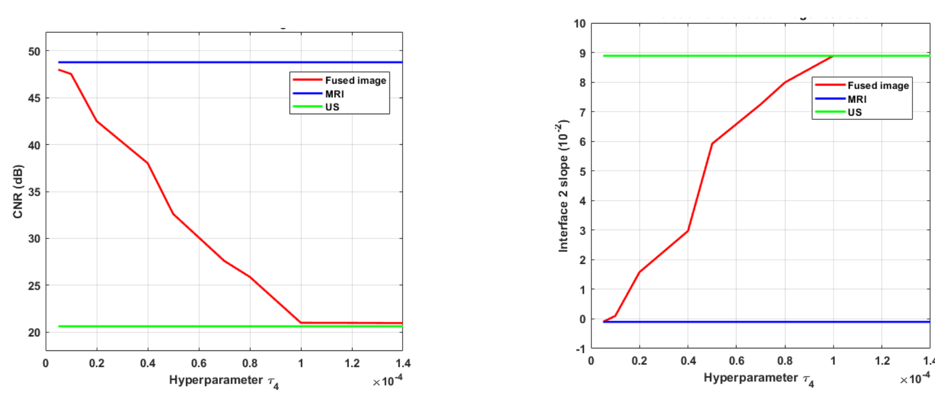

Fig. 2: Influence of the hyperparameter τ_4 on the fused image. (a) shows the CNR evolution whereas (b) shows the evolution of the interface 2 slope.

B. Comparison between several fusion methods for MRI and US images

1) Qualitative comparison results

This section demonstrates the efficiency of the proposed MRI/US fusion method, and presents some comparative results with different fusion techniques. We have considered a multi-scale Laplacian method [1] and a discrete wavelet transform [2] whose outputs are displayed in Figs. 3, 4, 5 and 6. In order to make a more fair comparison, we have denoised the US image before fusion since our proposed strategy also performs denoising. Figures below show the effect of noise on the fused image. For low SNR, the multi-scale fused image and the wavelet fused image contain distracting halos artifacts, especially in the regions containing strong transitions between organs (see Figs. 5 and 6).

SNR = 40dB

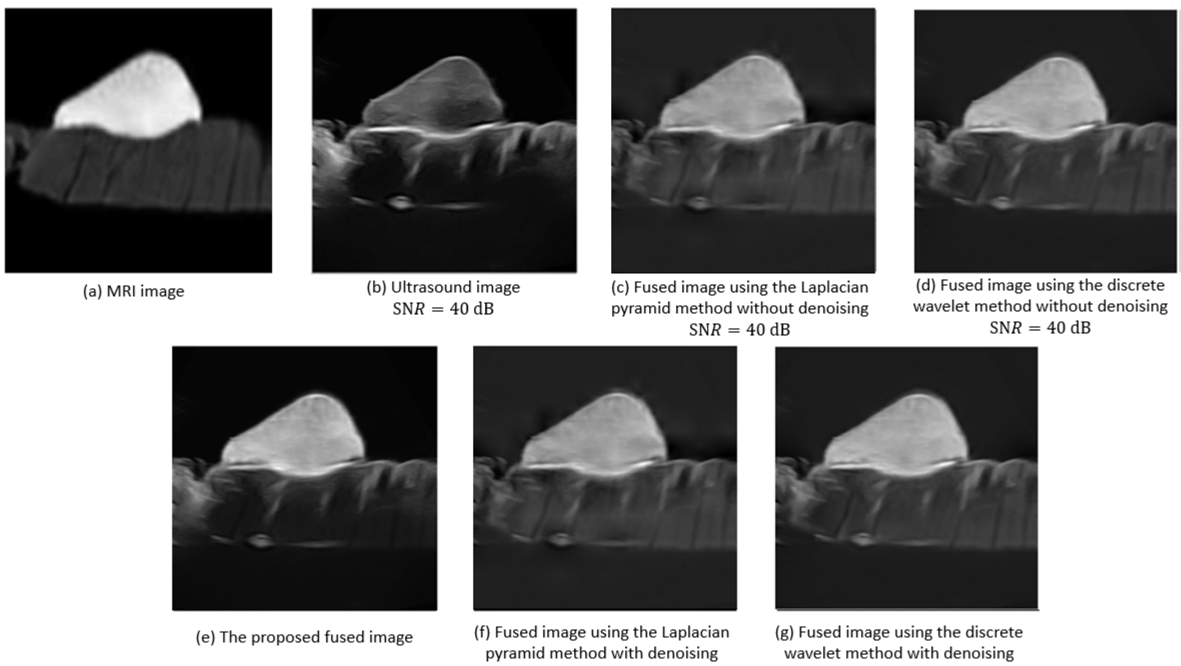

Fig. 3: Influence of SNR of the ultrasound image (SNR = 40dB) on the fused images, (a) and (b) are the MRI and US images, (c) and (d) show the fused images using respectively the Laplacian pyramid and the discrete wavelet methods without denoising the US image, (e) shows the fused image using the proposed method, (f) and (g) show the fused image using respectively the Multi-scale Laplacian pyramid and the discrete wavelet decomposition methods after denoising the US image.

SNR $= 25$dB

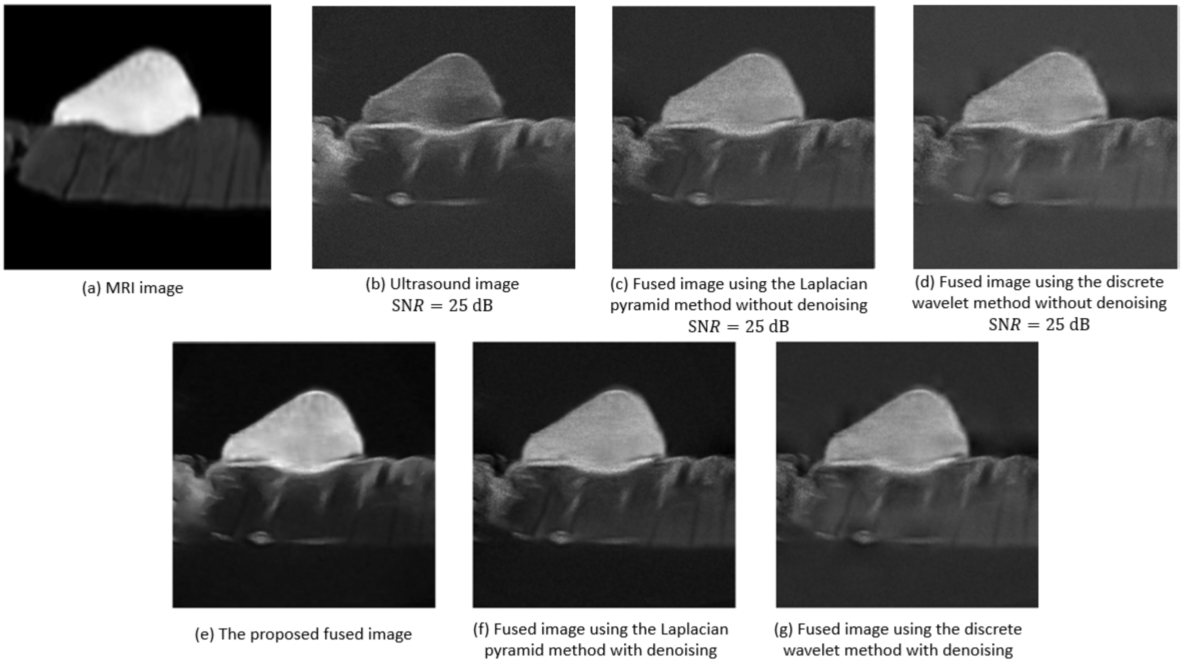

Fig. 4: Influence of SNR of the ultrasound image (SNR $= 25$dB) on the fused images, (a) and (b) are the MRI and US images, (c) and (d) show the fused images using respectively the Laplacian pyramid and the discrete wavelet methods without denoising the US image, (e) shows the fused image using the proposed method, (f) and (g) show the fused image using respectively the Multi-scale Laplacian pyramid and the discrete wavelet decomposition methods after denoising the US image.

SNR $= 10$dB

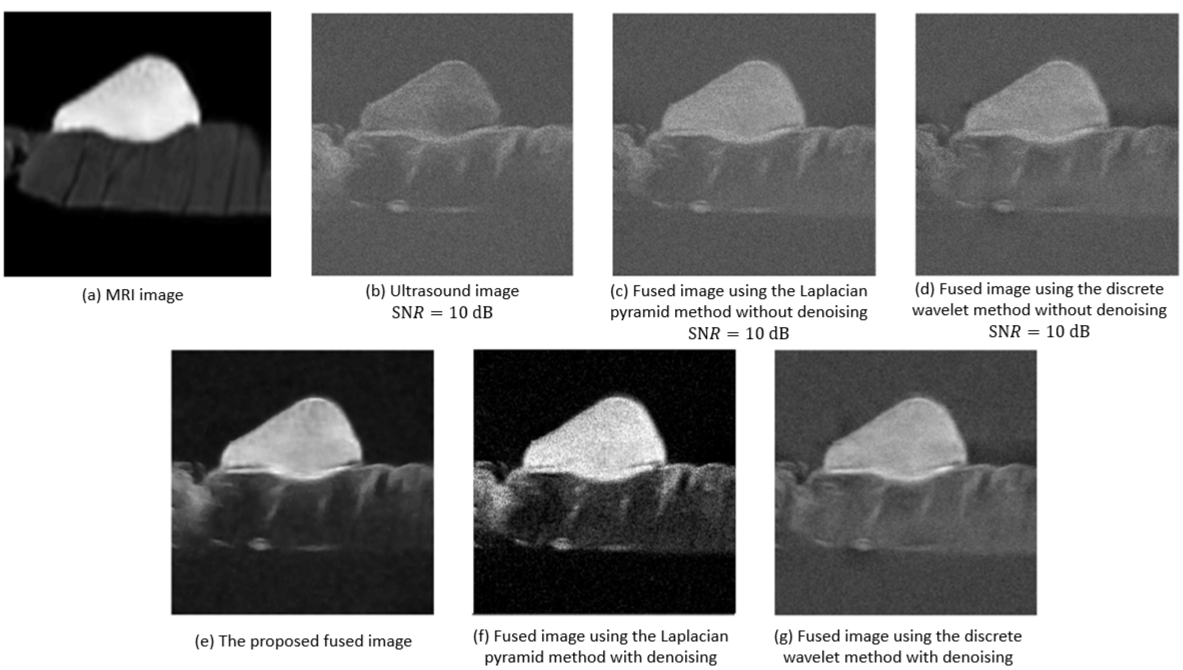

Fig. 5: Influence of SNR of the ultrasound image (SNR $= 10$dB) on the fused images, (a) and (b) are the MRI and US images, (c) and (d) show the fused images using respectively the Laplacian pyramid and the discrete wavelet methods without denoising the US image, (e) shows the fused image using the proposed method, (f) and (g) show the fused image using respectively the Multi-scale Laplacian pyramid and the discrete wavelet decomposition methods after denoising the US image.

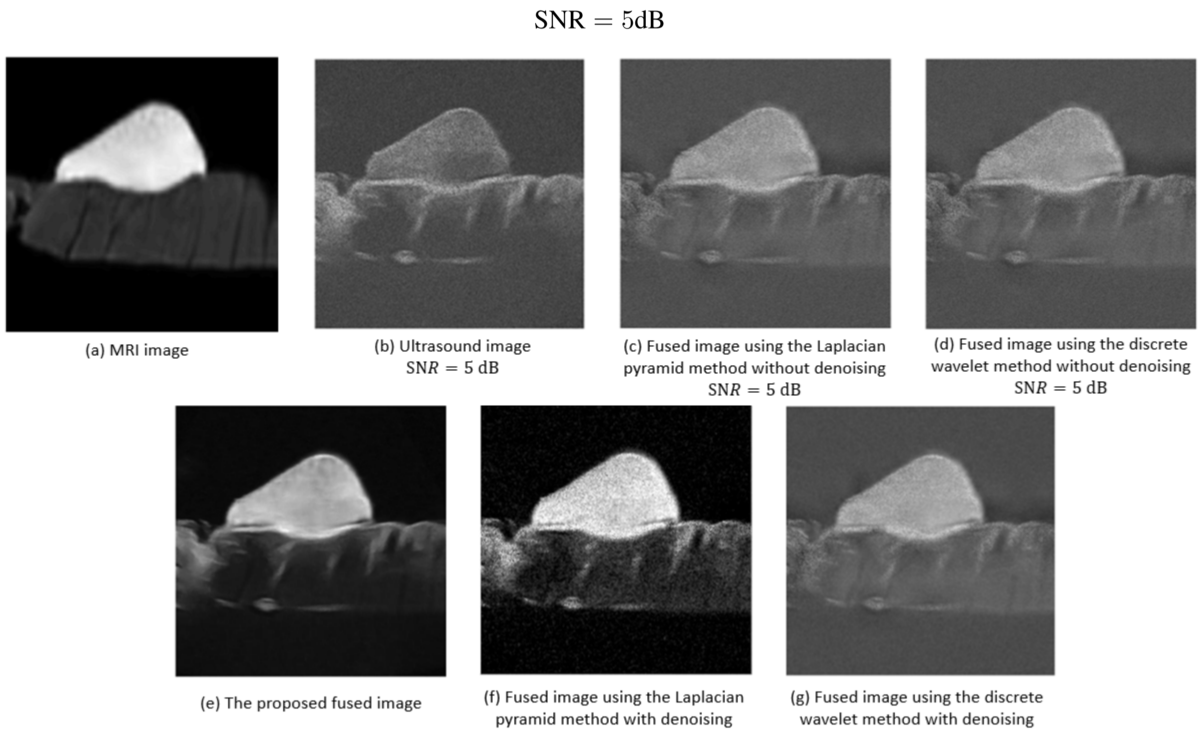

Fig. 6: Influence of SNR of the ultrasound image (SNR $= 5$dB) on the fused images, (a) and (b) are the MRI and US images, (c) and (d) show the fused images using respectively the Laplacian pyramid and the discrete wavelet methods without denoising the US image, (e) shows the fused image using the proposed method, (f) and (g) show the fused image using respectively the Multi-scale Laplacian pyramid and the discrete wavelet decomposition methods after denoising the US image.

2) Quantitative comparison results

The performance of the proposed fusion algorithm was evaluated using a quantitative metric, namely the Petrovic fusion metric [3]. This metric associates important visual information with the edge information in each pixel. Thus, a measure of fusion performance is obtained by evaluating the amount of edge information that is transferred from input images to the fuse image. Fig. 7 clearly demonstrates that for higher noise levels the fusion becomes more complicated.

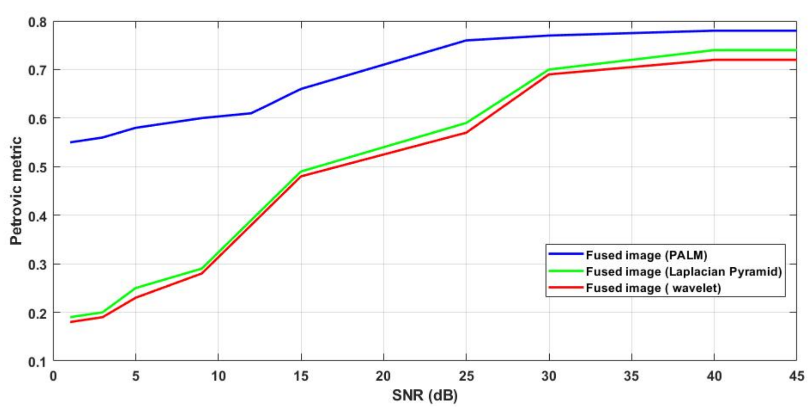

Fig. 7: Influence of SNR on the Petrovic metric for the fused images. The proposed fusion method is in blue, the Multi-scale Laplacian method is in green and the discrete wavelet transform fusion is in red.

References

[1] C. O. Ancuti, C. Ancuti, C. D. Vleeschouwer, and A. C. Bovik, "Single-scale fusion: An effective approach to merging images," *IEEE Trans. Image Processing*, vol. 26, no. 1, pp. 65–78, 2016.

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[3] V. Petrović, "Subjective tests for image fusion evaluation and objective metric validation," *Information Fusion*, vol. 8, no. 2, pp. 208–216, 2007.