IEEE GlobalSIP

Magnetic Resonance and computed Tomography Image Fusion using Bidimensional Empirical Mode Decomposition

Tariq Alshawi (King Saud University, KSA)
Fathi E. Abd El-Samie (Menoufia University, Egypt)
And Saleh A. Alshebeili (KACST-TIC, KSA)

جامعة الملك سعود
King Saud University

RFTONICS
KACST-TIC in Radio Frequency & Photonics for the e-Society

Outline

- Motivation
- Literature Review
- Bidimensional Empirical Mode Decomposition
- Intrinsic Mode Function Fusion
- Evaluation Methodology
- Experiments
- Results and Discussions
- Conclusions

Motivation

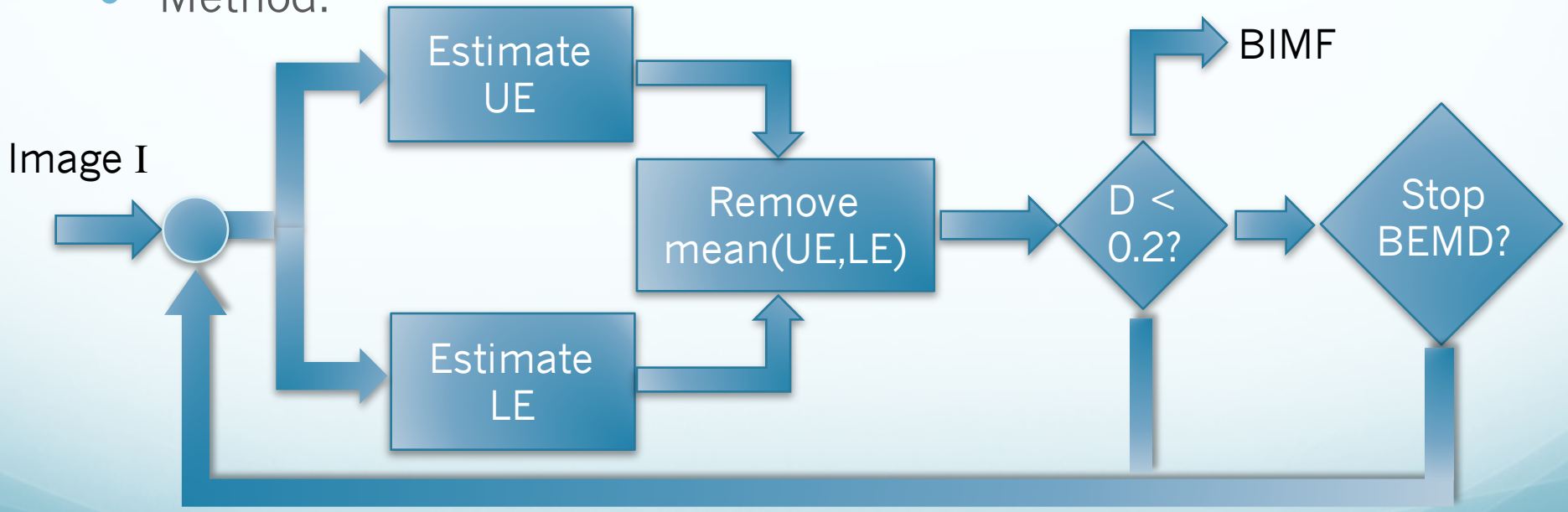
- Why Fusion?
  - Single Modality is limited
  - Fusion saves time and efforts
  - Improved performance in computational algorithms
- Why BEMD?
  - EMD is data-driven
  - Medical images are anatomically consistent
  - Computational efficient; possible to use on medical images

Literature Review

- Medical Image Fusion [1]
  - Multi-scale (Gaussian and Laplacian Pyramids)
  - Component Analysis-based
  - Wavelet-based
  - Curvelet-based [2]
- BEMD Fusion
  - Fast and Adaptive BEMD fusion [3]
  - Multi-focus image fusion [4]
  - Remote-sensing imagery [5]
  - Infrared and visible range image fusion [6]

Bidimensional Empirical Mode Decomposition (BEMD)

- Goal: represent non-linear non-stationary signals as the sum or zero-mean AM-FM components called Intrinsic Mode Function (IMF).
- Method:



BEMD (Example)

Original

BIMF 1

BEMD (Example)

Original

BIMF 2

BEMD (Example)

Original

BIMF 3

BEMD (Example)

Original

Residual

Fusion Rules

- Maximum Rule

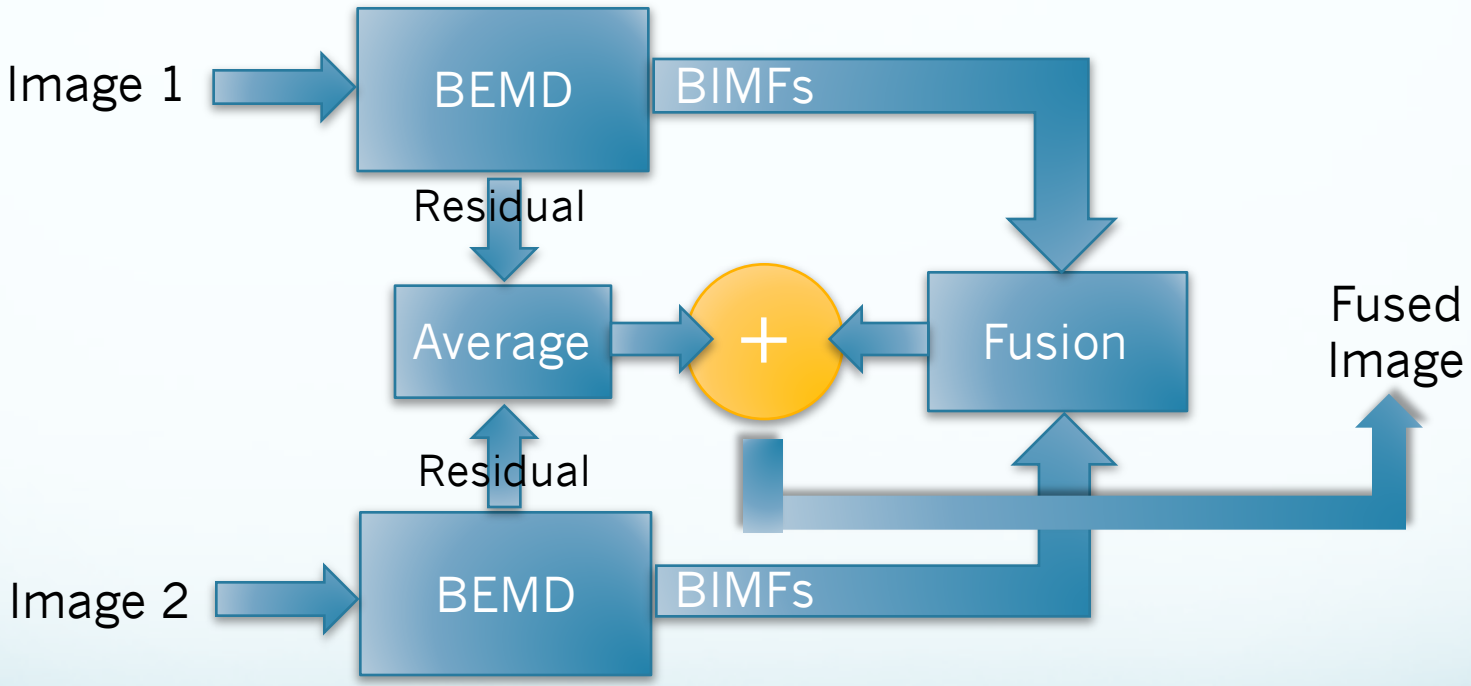
$$F_k(x,y) = max\left(\mathrm{BIMF}_k^{(1)}(x,y), \mathrm{BIMF}_k^{(2)}(x,y)\right)$$

- Variance Rule

$$F_k(x,y) = \begin{cases} \mathrm{BIMF}_k^{(1)}(x,y) & \text{if } \sigma_{(1)} > \sigma_{(2)} \\ \mathrm{BIMF}_k^{(2)}(x,y) & \text{Otherwise} \end{cases}$$

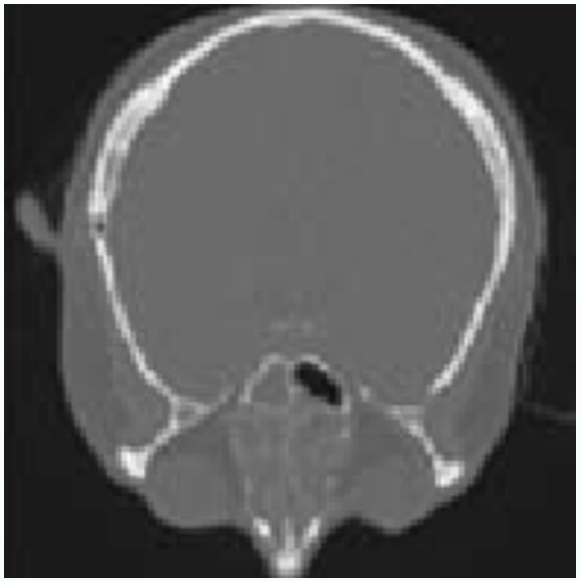
$$\sigma_{(r)} = \sum_{i=1}^{N}\sum_{j=1}^{N} \frac{(\mathrm{BIMF}_k^{(r)}(i,j) - \mu)^2}{N^2}$$

Proposed Method



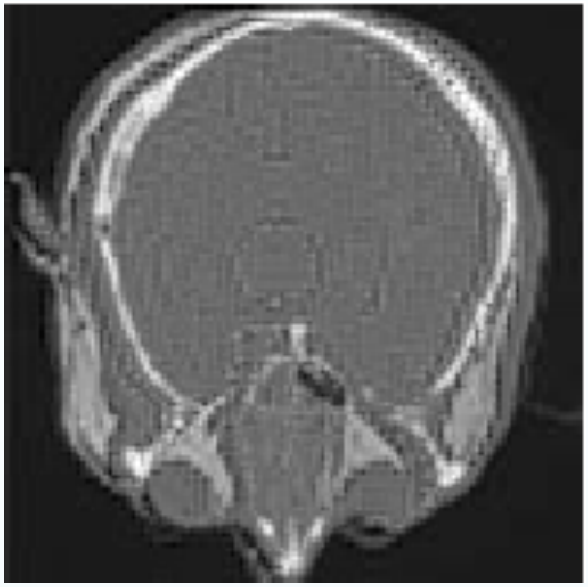
Results and Discussions

MRI

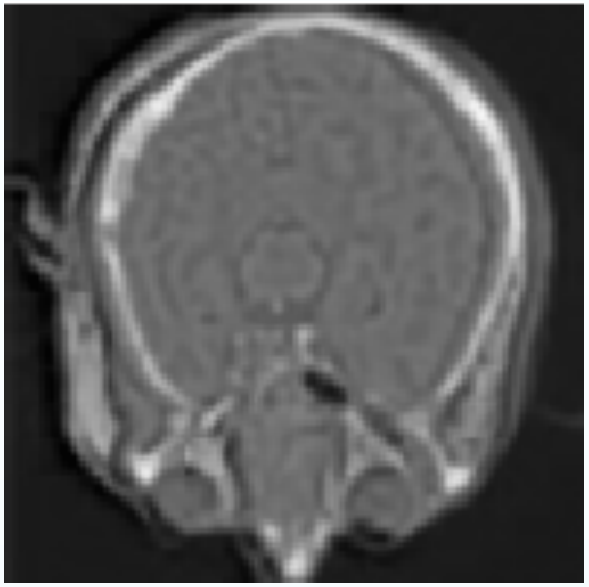


CT

Results and Discussions

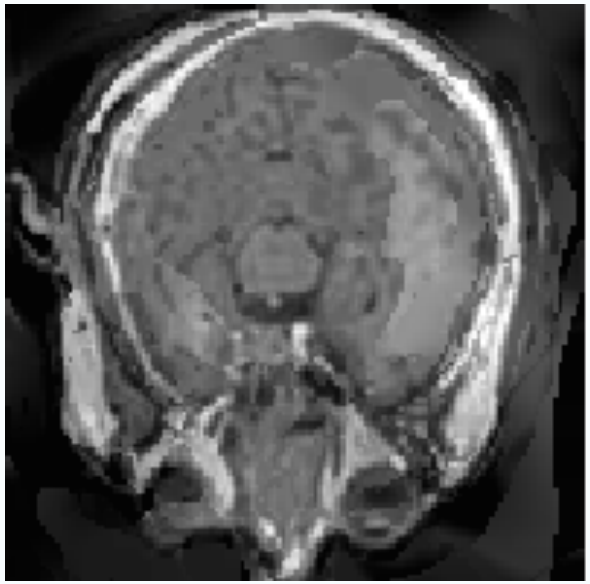


Wavelet-based [2]

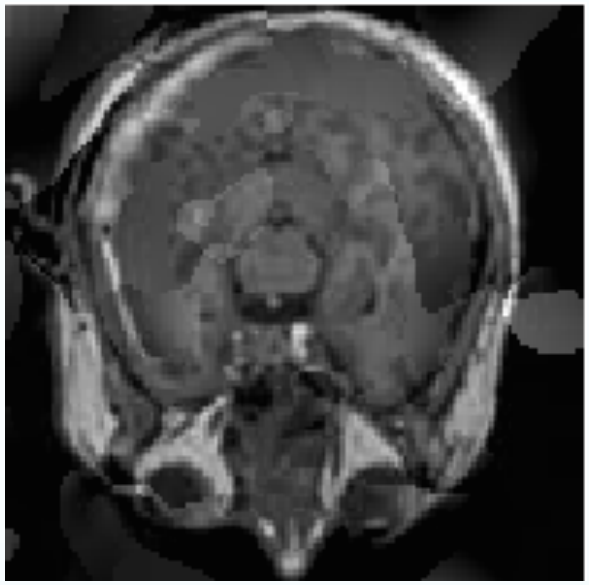


Curvelet-based [2]

Results and Discussions



BEMD - Maximum



BEMD - Variance

Results and Discussions

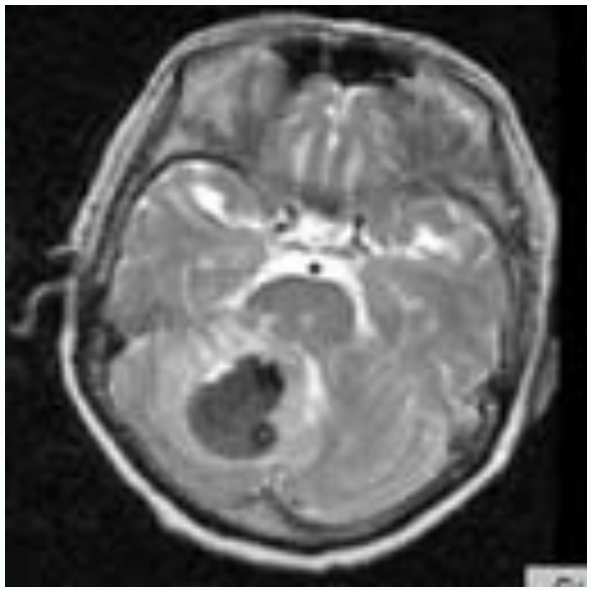


Image A

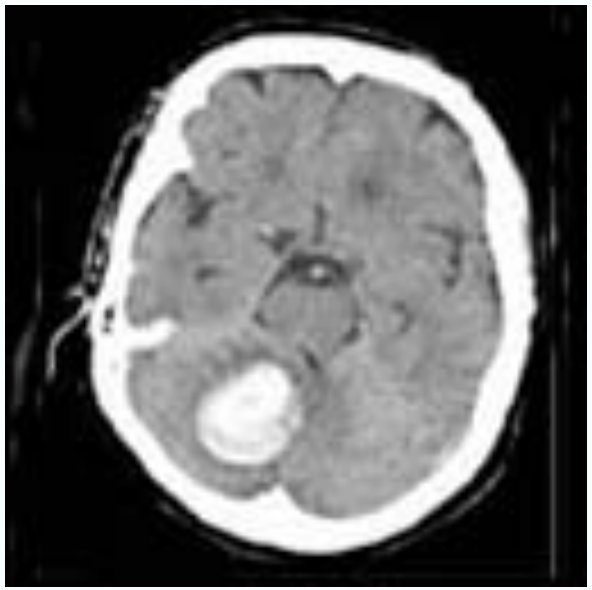
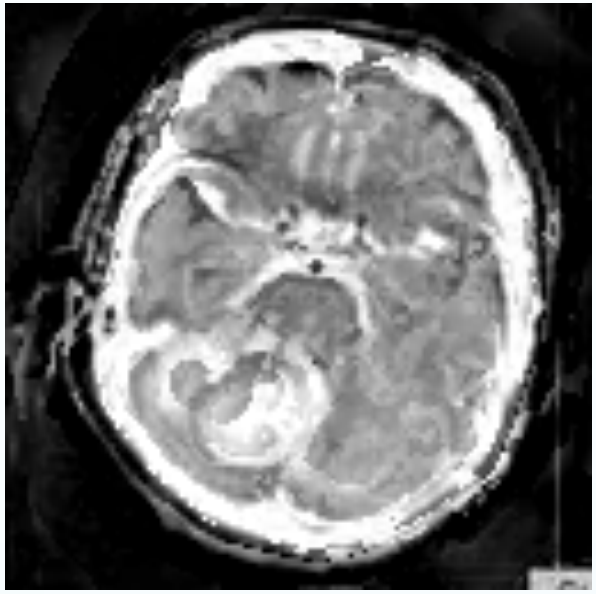
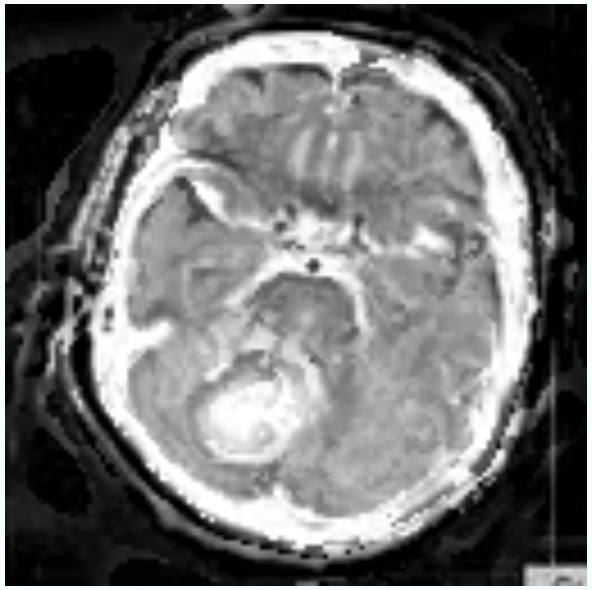


Image B

Results and Discussions



BEMD - Maximum



BEMD - Variance

Evaluation Metrics

- Peak Signal-to-Noise Ratio (PSNR):

$$\mathbf{PSNR} = 20 \cdot \log_{10}\big(max(I)\big) - 10 \cdot \log_{10}\big(\mathbf{MSE}\big)$$

- Structure Similarity (SSIM):

$$\mathbf{SSIM}(I, F) = \frac{(2\mu_{\mathrm{I}}\mu_{\mathrm{F}} + c_1)(2\sigma_{\mathrm{IF}} + c_2)}{(\mu_{\mathrm{I}}^2 + \mu_{\mathrm{F}}^2 + c_1)(\sigma_{\mathrm{I}}^2 + \sigma_{\mathrm{F}}^2 + c_2)}$$

- Mutual Information (MI):

$$\mathbf{MI}(I, F) = \sum_{i,f} p_{\mathrm{IF}}(i, f) \log \frac{p_{\mathrm{IF}}(i, f)}{p_{\mathrm{I}}(i)\, p_{\mathrm{F}}(f)}$$

Quantitative Results

Fusion Methods	PSNR	SSIM	Mutual Information
Wavelet	13.5392	0.3987	1.8537
Curvelet	13.7287	0.3314	1.7661
BEMD - Max	13.9845	0.5012	1.6638
BEMD - Var	**17.6223**	**0.5607**	**2.0926**

Conclusions

- Bidimensional Empirical Mode Decomposition is used in medical image fusion
- BEMD produces structurally homogenous components; easier to fuse computationally
- Patch variance fusion rule provides good results both in perceived quality and evaluation metric
- Future investigation should focus on designing an optimized fusion rule in BEMD space.

Thank You

Questions?

[1] A. James and B. Dasarathy, "Medical image fusion: A survey of the state of the art," Information Fusion, Vol. 19, pp. 4-19, Sept. 2014.
[2] F. E. Ali, I. M. El-Dokany, A. A. Saad, W. Al-Nuaimy, and F. E. Abd El-Samie, "High resolution image acquisition from magnetic resonance and computed tomography scans using curvelet fusion algorithm with inverse interpolation techniques," Applied Optics, Vol. 49, No.1, pp. 114-125, Jan. 2010
[3] M. U. Ahmed and D. Mandic, "Image fusion based on Fast and Adaptive Bidimensional Empirical Mode Decomposition," in Proc. Conf. Info. Fusion (FUSION), pp.1-6, 26-29 July 2010.
[4] . Chen, Y. Jiang, C. Wang, D. Wang, W. Li, and G. Zhai, "A novel multi-focus image fusion method based on bidimensional empirical mode decomposition," In Proc. Int. Cong. on Image and Signal Processing, pp.1-4, Tianjin, Oct. 2009.
[5] Z. Qian, L. Zhou, and G. Xu, "Bandlimited BEMD and application in remote sensing image fusion," In Proc. Int. Conf. on Remote Sensing, Environemnt and Transportation Enigneering (RESETE), pp. 2979-2982, Nanjing, June 2011.
[6] X. Zhang, Y. Liu, and J. Chen, "Fusion of the infrared and color visible images using bidimensional EMD," In Proc. Int. Conf. on MultiMedia and Info. Tech. (MMIT'08), pp. 257-260, Three Gorges, Dec. 2008.