

Improved Reconstruction of Highly Under-sampled MR angiography Images Using Modified Nonlocal Means

Y. Feng¹, Y. Mei¹, C. Wang¹, and W. Chen¹

¹School of Biomedical Engineering, Southern Medical University, Guangzhou, Guangdong, China, People's Republic of

Introduction

In dynamic MRI Angiography, data acquisition of each frame is usually reduced to a small amount due to the requirement of high spatio-temporal resolution, which will lead to poor image quality (including artifacts and noise) in reconstruction. Traditional method improves the spatial resolution of each frame image through the sliding-window filtering in temporal direction [1]. In this paper, a novel compromise between spatial and temporal resolution is proposed through modifying nonlocal-means (NLM) filtering [2]: the reference image with more details (corresponding to high spatial resolution), reconstructed from more data, were incorporated as the prior information into the restoration of image from less data (corresponding to high temporal resolution). It is shown to be able to eliminate the artifacts and enhance the image details for highly under-sampled MR Angiography

Methods:

Non-local means (NLM) method, which reduces noise in image while preserving edge details very well, was originally proposed by Buades et al [1] and generalized to medical image denoising and reconstruction [3]. The averaging in NLM assigns high weights to those pixels that have similar surrounding patches to the patch around the current pixel. The NLM method was modified to combining the high-spatial-resolution (HSR) image and the high-temporal-resolution (HTR) image and the detailed diagram is shown in Fig. 1.

Temp images are reconstructed using gridding algorithm from data being combined along temporal direction with the rectangle window function. Narrow window will produce HSR image and wide window will produce HTR image. The restoration of details in HTR image with prior information form HSR image can be formulated as:

$$NL(I_{HTR})(x_i) = \sum_{j \in I_{HSR}} w(x_i, x_j) I_{HSR}(x_j) \quad (1)$$

Where I denotes image, and the weight factor $w(x_i, x_j)$ is calculated as:

$$w(x_i, x_j) = Z_i^{-1} \exp(-\|u_{i_{HTR}}(N_i) - u_{j_{HSR}}(N_j)\|_2^2 / h^2) \quad (2)$$

Here, N_i denotes a neighborhood (patch) of pixel i , $u(N_i)$ is a vector containing the intensities of pixel inside N_i , $\|u(N_i) - u(N_j)\|_2$ is the Euclidean distance as a measure of similarity between two patches, h^2 controls the decay of the exponential function and Z_i is a normalization factor.

According to Eq. (1) and Eq. (2), only the pixels in the HSR image whose surrounding patches find out similar patches in the HTR image are highly weighted during image combining. This means an enhancement of the details in the HTR image without introducing dissimilar structures.

Data were simulated on variable density spirals using collected projection X-ray of an arterial bolus injection in a patient with an AVM (NFS_NZWA_09AUG06 from ISMRM website: http://www.ismrm.org/mri_unbound/). Gridding with Kaiser-Bessel convolution kernel was implemented [4]. The parameter h in Eq. (2) was calculated adaptively as described in [5].

Results

30 interleaved spirals were used for HTR image reconstruction and 80 spirals for HSR image. Figure 2 shows the preliminary results of the proposed method and that of traditional sliding window method, only frame 50th and 140th were chosen as a demonstration. The number of spirals used for Hanning window was 60 while that of the proposed method was only 30. As can be seen, the noise and artifacts are dramatically reduced, leading to an enhancement of the image details.

Conclusion

In this paper, high spatio-temporal resolution is accomplished using a novel combination of the HTR and HSR images based on the modified NLM method. Preliminary experiments of simulated data demonstrate that the proposed method is of great potential for the reconstruction of highly under-sampled MR Angiography.

Reference

[1] B. Madore et al, MRM, 42:813–828, [2] A. Buades et al, Technical Report 2004-15, CMLA, [3] G. Adluru et al, ICPR 2010, [4] J. I. Jackson et al, IEEE TMI, 10(3):473-8, [5] P. Coupe, IEEE TMI, 27(4):425-441.

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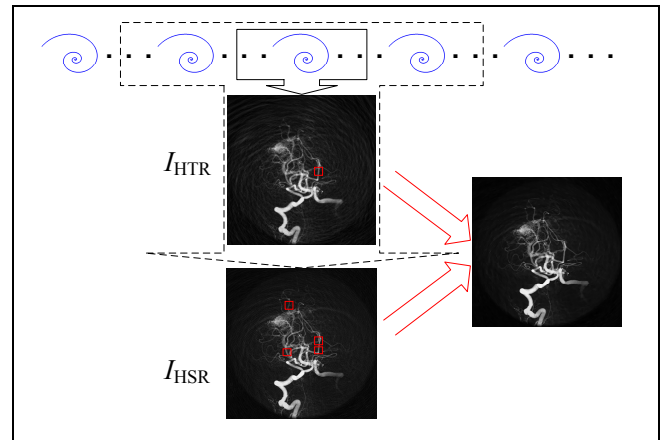


Fig. 1 Block diagram for Reconstruction Using Modified Nonlocal Means

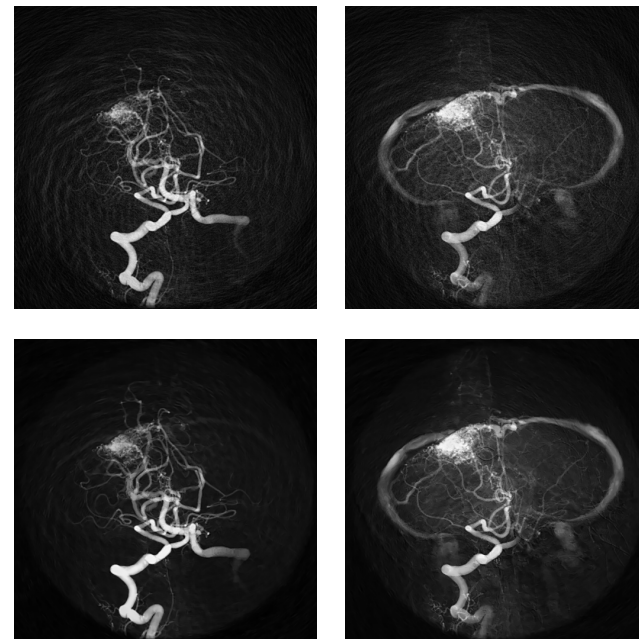


Fig. 2 Results of reconstruction.

Up: reconstruction with the temporal Hanning filtering; Down: the proposed method.