High Resolution 3-D MR Image Reconstruction from Multiple Views

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CONTENTS

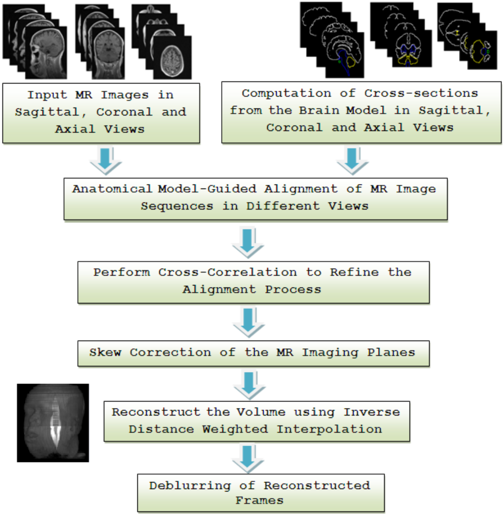
PROBLEM STATEMENT

Reconstruction of a 3D high resolution volume from 2D image slices of multiple views.

Problems associated are:

- Intensity inhomogeneity of the MR images in different views
- Different spatial resolutions in the three views for T_1- or T_2-weighted scans
- Registration of the MR image sequences in multiple views

Block Diagram of the Proposed Method



Normalization of Intensity Values in MR Image Sequences of Multiple Views

Parameters that influence the image contrast:

- Dependent parameters: Relaxation times T_1 and T_2, Spin density
- Technical parameters: Echo time (TE) and Repetition time (TR)

TR and TE are adjusted to control intensity values of the images [1] .

[1] Suetens, *Fundamentals of Medical Imaging*, Cambridge University Press, 2002.

Model-Guided Alignment and Resizing of MR Image Sequences

- Model-Guided Alignment: Mapping each individual image in a sequence of MR images to a human brain model.
- The Model Based MRI Alignment (MBMRIA) algorithm [1]:

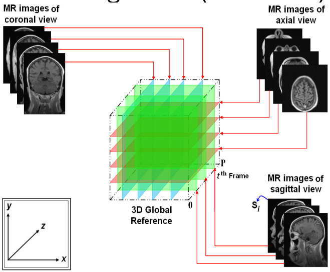


Figure 1: Alignment of MR images of different views.

[1] Mondal *et al.*, *An Efficient Model-Guided Framework for Alignment of Brain MR Image Sequences*, SMC, 2012.

Normalized Cross-Correlation to Refine the Alignment Process

- Normalized cross-correlation for adjusting the relative positions of frames of two views.
- Cross-Correlation: The rows of S_i and A_k are aligned.

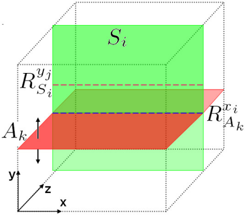


Figure 2: S_i: i^{th} sagittal image, C_j: j^{th} coronal image, A_k: k^{th} axial image, rows of S_i: $R^{y_j}_{S_i}$, and rows of A_k: $R^{x_i}_{A_k}$

Skew Correction of the MR Imaging Planes

- MR images are aligned parallel to *xy*-, *yz*- or *zx*- planes.
- MR sequences are skew corrected to maintain the rectilinear configuration of principal coordinate planes.

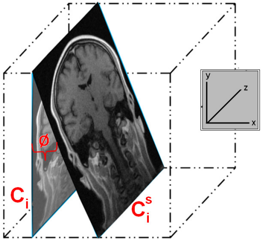


Figure 3: Skew correction along the *yz*-plane in coronal view.

Skew Correction

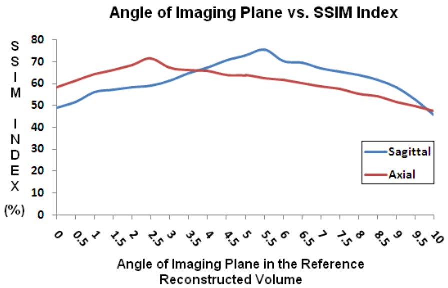


Figure 4: Plot of SSIM measured between reference MR images and cross-sections computed from the volume in different angles.

- QUADRA datasets: The skews for MR images of sagittal and axial views are 5.65^0 and 2.85^0, respectively.

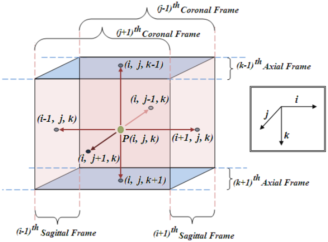
HIGH RESOLUTION VOLUME RECONSTRUCTION

Resolution: inter-slice gap between two cross-sections along any view.

The proposed volume reconstruction method is based on inverse distance weighted (IDW) interpolation scheme.

Alignment Followed by Interpolation (AFI)

- The volume reconstruction problem: Finding intensity values of the interior pixels of a cube with known functional values at surface points.
- Computational complexity is reduced by considering six nearest sample points on the surface.



Alignment Followed by Interpolation (AFI)

- Considering more than 6 neighbors do not significantly improve quality of the reconstructed volume as compared to 14 neighbors.
- Time consumed for the 14 neighbor case is more than twice the 6 neighbor one.

Deblurring of Reconstructed Images

- Interpolation causes blurring of images.
- Deblurring is performed using Richardson-Lucy (R-L) algorithm [1].

[1] Richardson, *Bayesian-Based Iterative Method of Image Restoration*, JOSA, 1972.

EXPERIMENTAL RESULTS

Datasets

- Experimentation: Acquired from the Quadra Medical Services Pvt. Ltd, Kolkata, India.
- Validation: Obtained from the Open Access Series of Imaging Studies (OASIS).

The AFI method is applied on 20 different human brain MR image sequences.

AFI vs. Simple Interpolation

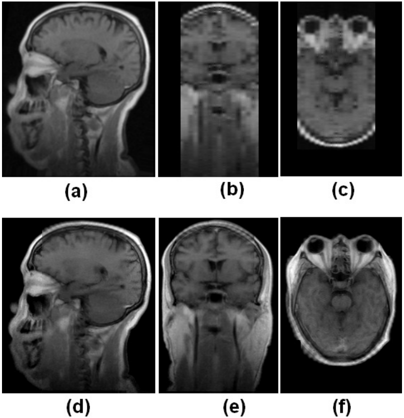


Figure 5: (a)-(c): Simple interpolation and (d)-(f): AFI.

Interpolation of Frames Between Two Successive MR Images using AFI

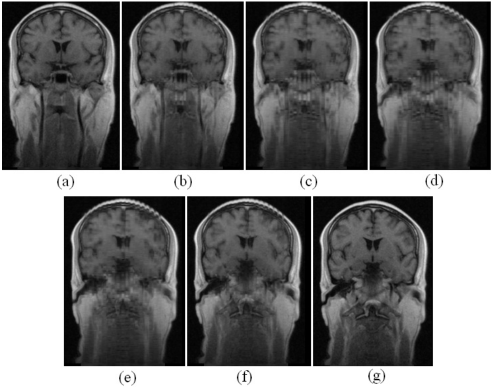


Figure 6: (a) and (g): Original successive MR images in a sequence of coronal view. (b)-(f): The intermediate interpolated frames.

Reconstructed Frames using the AFI and Reference Frames

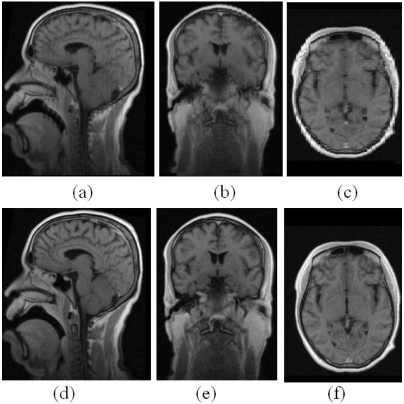
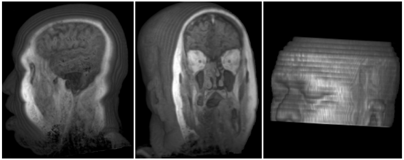
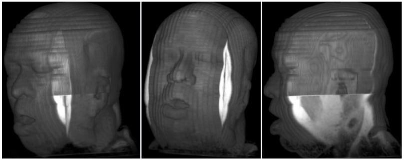


Figure 7: (a,b,c) represent the image slices generated from the volume in sagittal, coronal and axial views using the AFI technique, (d,e,f) depict the respective reference frames.

Reconstructed High Resolution Volumes vs. Low Resolution Volumes



(a)



(b)

Figure 8: (a) Low resolution volumes generated from different views. (b) High resolution volumes generated using the AFI technique.

Deblurring of Reconstructed Frames

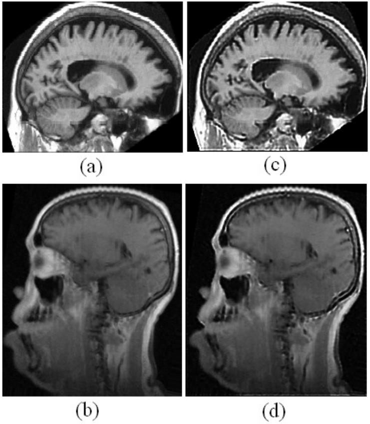


Figure 9: Reconstructed frames (a,b) using AFI and their corresponding deblurred images (c,d) for the Quadra and the OASIS datasets.

Oblique Views from Reconstructed Volume

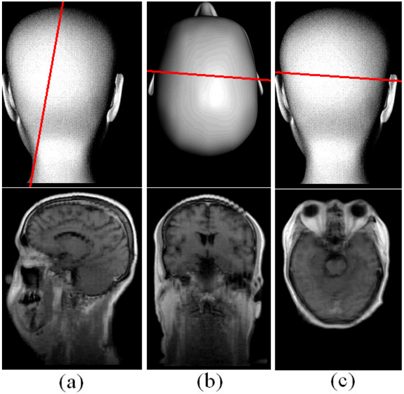


Figure 10: Oblique imaging planes and their corresponding cross-sections computed using AFI algorithm in (a) sagittal, (b) coronal and (c) axial views.

Experiments on the Quadra Datasets

Table 1: Quadra Datasets: SSIM index computed between the reconstructed images and the reference frames.

Reconstructed MR Image Sequences from	**Image Plane**	**SSIM Index**	
		AFI	**Deblurred**
Sagittal & Coronal	Axial	68.24	74.38
Sagittal & Axial	Coronal	72.59	77.73
Coronal & Axial	Sagittal	72.42	76.17

Experiments on the OASIS Datasets

Table 2: OASIS Datasets: SSIM index computed between the reconstructed images and the reference frames.

Reconstructed MR Image Sequences from	Image Plane	SSIM Index	
		AFI	Deblurred
Sagittal & Coronal	Sagittal	93.82	98.23
	Coronal	94.73	97.82
	Axial	83.19	88.31
Sagittal & Axial	Sagittal	92.47	96.72
	Coronal	84.21	92.16
	Axial	91.95	93.74
Coronal & Axial	Sagittal	82.02	90.37
	Coronal	90.38	95.31
	Axial	92.83	96.23
Sagittal, Coronal & Axial	Sagittal	92.02	97.19
	Coronal	91.26	95.49
	Axial	93.30	95.28

CONCLUSION

- An efficient technique has been proposed to reconstruct a high resolution human brain volume from multiple low resolution MR image sequences.
- It can be used to study smaller structures of brain, e.g., a lesion within a reconstructed volume.

REFERENCES

P. Mondal, J. Mukhopadhyay, S. Sural and P. P. Bhattacharyya.
An Efficient Model-Guided Framework for Alignment of Brain MR Image Sequences.
IEEE International Conference on Systems, Man, and Cybernetics, pages 2201-2206, 2012.

P. Suetens.
Fundamentals of Medical Imaging.
Cambridge University Press, 2002.

The Open Access Series of Imaging Studies (OASIS).
http://www.oasis-brains.org/.

W. H. Richardson.
Bayesian-Based Iterative Method of Image Restoration.
Journal of the Optical Society of America, 62(1):55-59, 1972.

Anatomy Model Store.
http://www.plasticboy.co.uk/store/.

Thank You