# Super-Resolution Reconstruction of MRI

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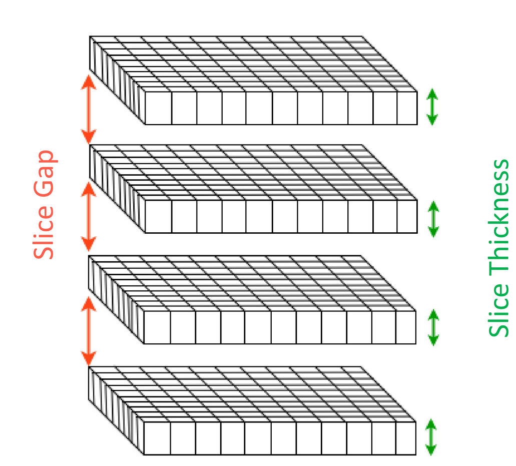
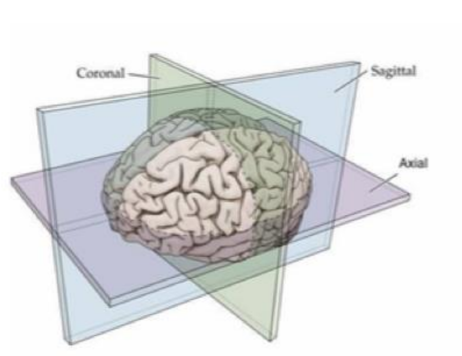
## Introduction

Magnetic Resonance Imaging (MRI) is a non-invasive technique that is used in clinical applications such as diseases diagnosis and monitoring and treatment progress. Although, MRI scans typically have high in-plane resolution but they have very poor resolution in slice direction. Furthermore, in some applications with limited acquisition time or where the subject is moving, increased slice thickness or inter-slice space (slice gaps) may be used which results in poor resolution MRI.

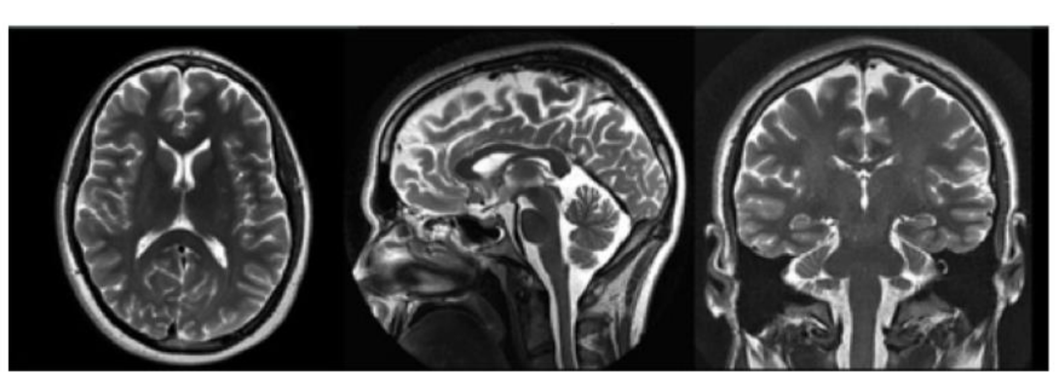
In this research, we propose a novel Super-Resolution (SR) technique for reconstructing High-Resolution (HR) MRI using a sequence of orthogonal Low-Resolution (LR) MRI scans.



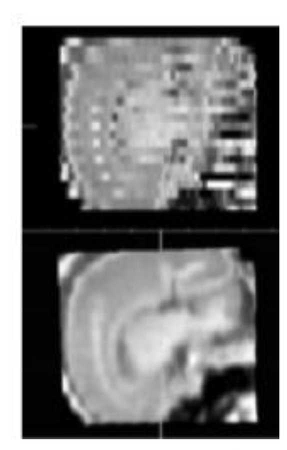

The resolution of this reconstructed SR MRI is improved in all directions and its information is increased comparing to the initial scans.




Ref.: www.rci.rutgers.edu
Orthogonal Views



Orthogonal Views of Brain: Axial, Sagittal, and Coronal

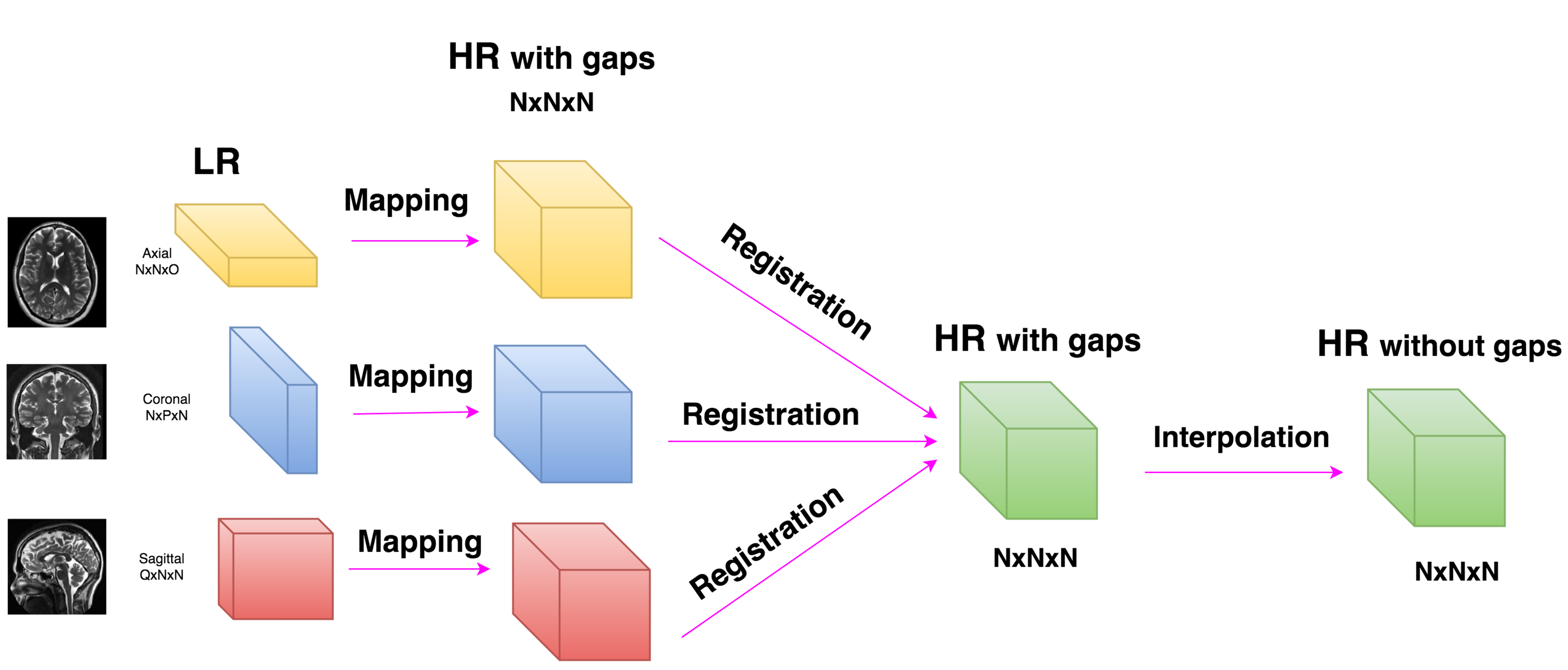


Motion Artefact

## Methods

In this study, an interpolation-based SR reconstruction method is proposed that is composed of three main steps.

- First, each LR volume is mapped onto a HR grid based on the prior knowledge of slice gap and slice thickness.
- Second, these HR grids are registered using mutual information registration method.
- Finally, these HR grids are combined and interpolated to fill in the remaining gaps in HR volume.



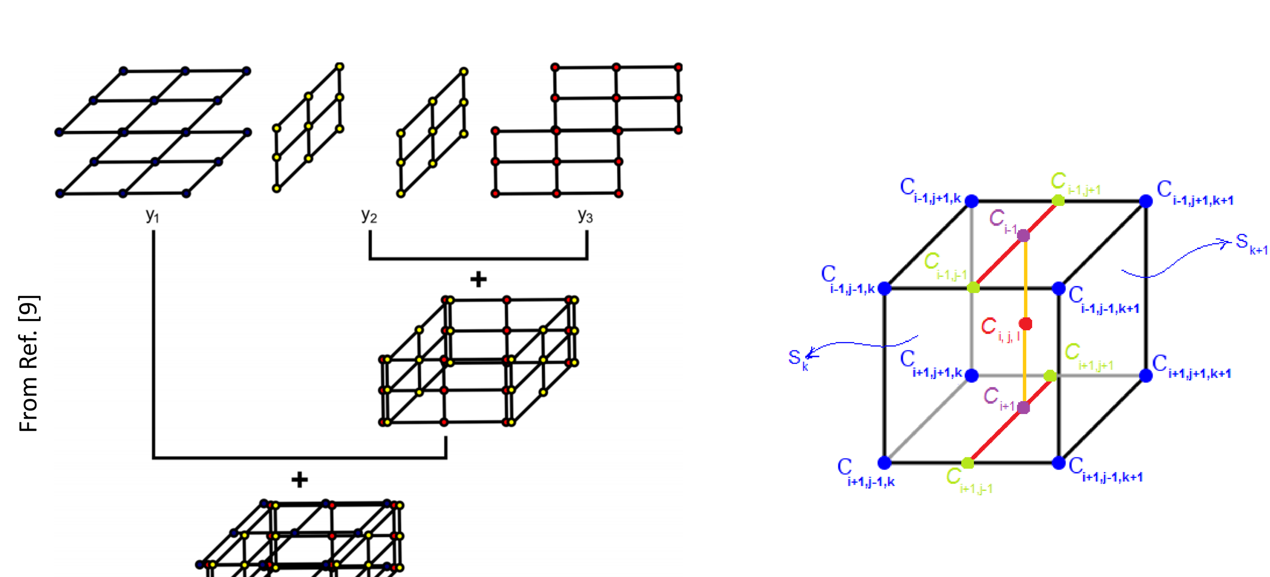
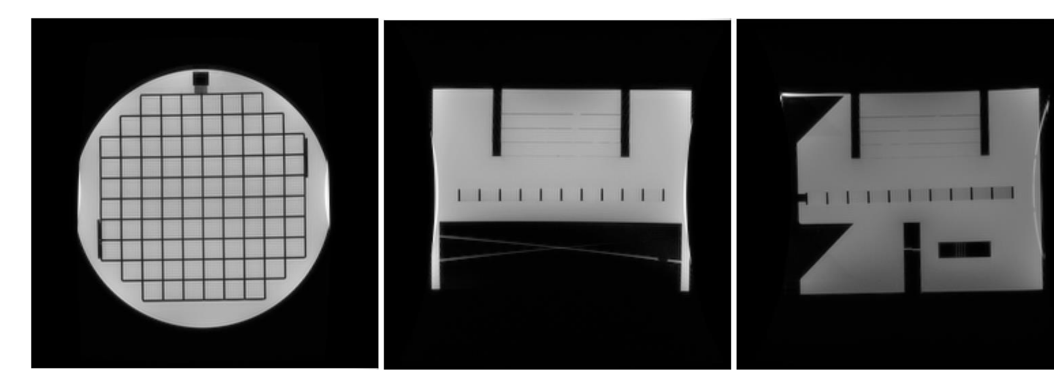




Illustration of Combination and Interpolation Scheme

## Discussion

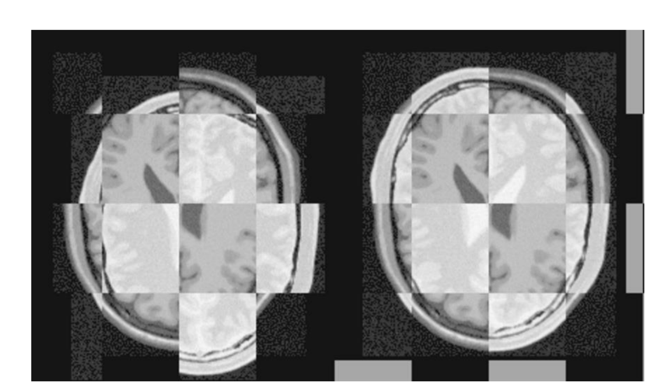
Robustness and accuracy of this method is tested on available datasets including synthetic and real orthogonal MRIs of human brain, and the American College of Radiology (ACR) Phantom with different slice gaps.

ACR MRI Phantom.



Orthogonal Views of ACR Phantom.

The most challenging part of proposed SR reconstruction method is image registration in which images are brought into correct alignment automatically. Mutual Information (MI) is among the most successful methods for rigid registration. Since human brain has very little change and can be considered as a rigid body, therefore MI image registration is one of the best options for our application. The performance of the image registration method is evaluated both qualitatively and quantitatively using techniques such as checkerboard layout, RMSE, and edge sharpness.



Checkerboard Evaluation

## Conclusion

In this study, an interpolation-based method for reconstructing SR MRI from a sequence of orthogonal LR MRIs is developed and tested on multiple synthetic and real datasets including MRIs of Phantom and human brain.
The results are evaluated both qualitatively and quantitatively. This method could be extended to cases with a motion correction step to handle motion artifacts or to reconstruct super resolution multi-modality images.

## Reference

1. P. Milanfar, *Super-Resolution Imaging*. CRC Press, 2010.
2. S. Kim, N. Bose, and H. Valenzuela, "Recursive reconstruction of high resolution image from noisy undersampled multiframes," *IEEE Transactions on Acoustics Speech and Signal Processing*, vol. 38, no. 6, pp. 1013–1027, 1990.
3. F. Rousseau, O. A. Glenn, B. Iordanova, C. Rodriguez-Carranza, D. B. Vigneron, J. A. Barkovich, and C. Studholme, "Registration-based approach for reconstruction of high-resolution in utero fetal mr brain images," *Acad Radiol*, vol. 13, pp. 1072–1081, Sep. 2006.
4. A. Gholipor and S. K. Warfield, "Super-resolution reconstruction of fetal brain mri," *MICCAI Workshop*, Sep. 2009.
5. A. Gholipour, J. A. Estroff, and S. K. Warfield, "Robust super-resolution volume reconstruction from slice acquisitions: application to fetal brain mri," *IEEE Trans Med Imaging*, vol. 29, pp. 1739–1758, Oct. 2010.
6. A. Gholipour, O. Afacan, I. Aganj, B. Scherrer, S. P. Prabhu, M. Sahin, and S. K. Warfield, "Super-resolution reconstruction in frequency, image, and wavelet domains to reduce through-plane partial voluming in mri," *Medical Physics.*, vol. 42, pp. 6919–6932, Dec. 2015.
7. B. Scherrer, A. Gholipour, and S. K. Warfield, "Super-resolution in diffusion-weighted imaging," *Med Image Comput Comput Assist Interv*, vol. 14, no. 2, pp. 124–132, 2011.
8. B. Scherrer, A. Gholipour, and S. Warfield, "Super-resolution reconstruction of diffusion-weighted images from distortion compensated orthogonal anisotropic acquisitions," *Mathematical Methods in Biomedical Image Analysis (MMBIA), 2012 IEEE Workshop on*, Jan 2012.
9. N. H. Kashou, M. A. Smith, and C. J. Roberts, "Ameliorating slice gaps in multislice magnetic resonance images: an interpolation scheme," *Int J Comput Assist Radiol Surg.*, vol. 10, pp. 19–33, Jan 2015.