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Realistic MRI simulation pipeline for anatomically variable normal young, aging and diseased brain

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INTRODUCTION

To make simulated MRI more realistic, a number of factors need to take into account. These factors include

- The use of finely structured phantoms with comprehensive tissue classes
- True tissue relaxation times
- Realistic simulation
- Realistic reconstruction

All these elements are integrated in our simulation pipeline. Furthermore, there are not enough large sets of MRI data available, for the purpose of training and validating medical imaging analysis algorithms. Using our simulation pipeline, a first set of anatomically variable simulated brain MRI images are created across age and gender.

METHODS

- A pipeline is designed for simulating realistic brain MRI as shown in Figure 1. The pipeline includes the use of the whole body 4D XCAT phantom, JEMRIS simulation software and clinically used Philips reconstruction pipeline.

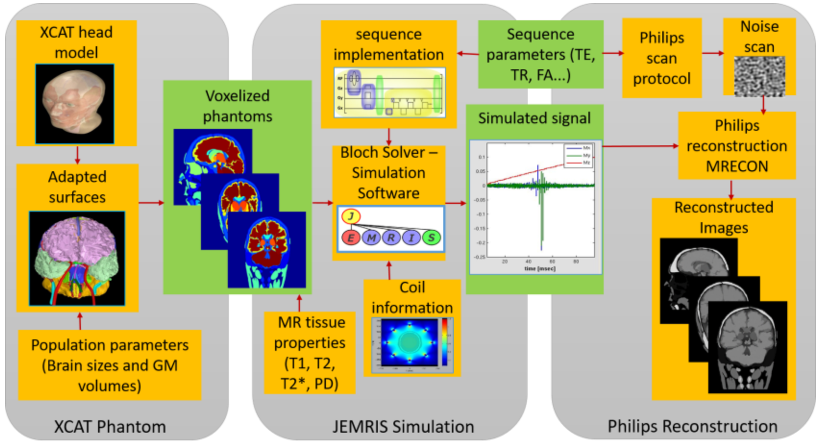

Figure 1: The pipeline designed for simulating realistic MR images, making use of XCAT phantom, JEMRIS simulation software and clinically used Philips reconstruction tools.

- Using XCAT complete head phantom, sixteen head phantoms are generated with three kinds of brain anatomical variations.
- The variations include different brain sizes, brain cortical gray matter volumes, and MS lesions.
- All generated phantoms are voxelized at an isotropic resolution of 0.5 mm^3 from the NURBS surfaces. And diverse tissue properties from the literature are assigned to the voxelized phantoms.
- 2D gradient echo T1w MRI images are simulated for one slice per phantom across axial, sagittal and coronal view using open source numerical Bloch-solver simulation software, JEMRIS.
- Simulated k-space data is fed into the reconstruction pipeline that is used on Philips clinical MRI scanners, for realistic reconstruction.

RESULTS

- Significant contrast was generated in simulated MRI. Such that in addition to the brain soft tissues, deep gray structures like putamen, thalamus, globus pallidus and caudate nucleus were also visible.
- Simulated T1w MRI's were generated for variations across brain sizes, cortical gray matter volumes and MS lesions (shown in Figure 2, 3, and 4 respectively).
- Per slice simulation time was ~20 min on 16 core processor.
- Significant reconstruction improvement was seen as smooth boundaries and reduced Gibbs artifacts (shown in Figure 5)

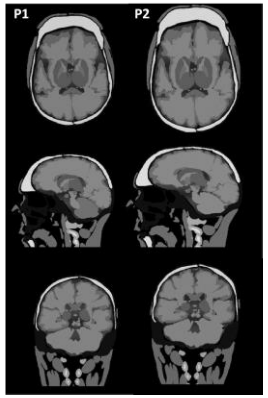

Figure 2: Simulated T1w MRI for two Phantoms with different brain sizes across axial, sagittal and coronal view.

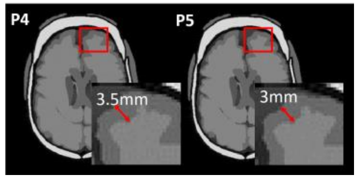

Figure 3: Simulated T1w MRI for two Phantoms with different brain normalized GM volumes across axial view with inset of zoomed superior frontal gyrus, along with cortical thickness measurement.

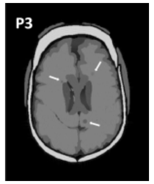

Figure 4: Simulated T1w MRI for Phantom with three spherical lesions.

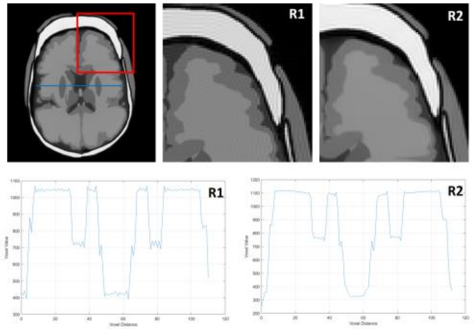

Figure 5: FFT reconstruction (R1) and commercial Philips reconstruction (R2) for simulated MRI, with inset zoomed area to compare reconstructed images quality. Also intensity profiles across R1 and R2 are presented, to validate the Gibbs artifact reduction in phase encoding direction.

CONCLUSION

- Using our pipeline, all anatomical variations are realistically represented in the simulated images.
- Detailed brain phantom and true relaxation times for each deep gray structure, has provided a significant contrast for deep gray structures visualization.
- Clinically used realistic reconstruction pipeline has generated simulated images with reduced artifacts, while maintaining fine contrasted edges with limited partial volume effects.
- The simulated images contain no noise, field inhomogeneities and variations within tissues yet, and is a work for future.