Transcranial ultrasound simulation using a learned mapping from MR to pseudo-CT images

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1. Motivation

Treatment planning simulations for Transcranial Ultrasound Stimulation (TUS) currently rely on mapping the skull from CT images. However, such images are not always available. Can deep learning be leveraged to allow T1-weighted MR images to be used instead?

2. Methods

We implemented a convolutional neural network (U-Net) to perform image-to-image translation from a T1-weighted MR image to a pseudo-CT image [1,2]. The network was trained on pairs of registered MR and CT images from patients who had previously undergone MR-guided focused ultrasound surgery. The impact of different network architectures, loss functions, and training parameters was explored.

To assess the generated images, 3D acoustic simulations were run using k-Wave based on both the real CT and the pseudo-CT images [3]. The predicted intracranial pressure fields were then compared for targets in the visual and motor cortices.

3. Results

For the skulls tested so far (see figure for an example), the difference in focal volume and the difference in peak pressure were both less than 10%. This suggests that using deep learning to generate pCTs from MR images for acoustic simulations is a promising avenue. Future work will provide a more detailed statistical analysis of the image and acoustic difference metrics between the different network architectures.

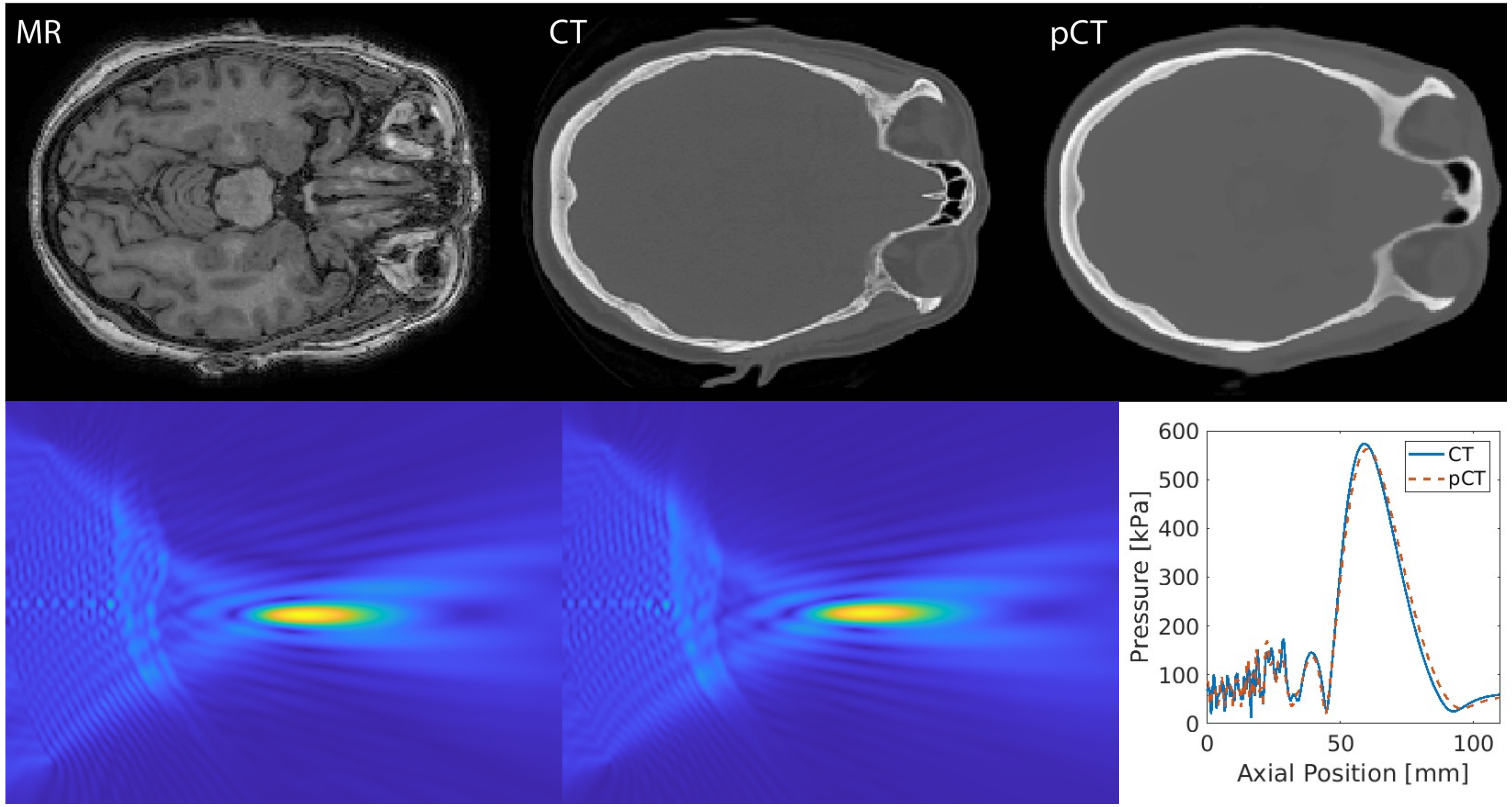

Figure: (top row) Example of slices through MR, CT, and pseudo-CT images (generated from the MR image using the trained network) for a skull from the test set. (bottom row) 3D acoustic simulations performed using k-Wave for a target in the visual cortex using CT and pseudo-CT images. The predicted acoustic fields are quantitatively very similar.

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[1] Ronneberger et al, (2015) ‘U-net: Convolutional networks for biomedical image segmentation’, MICCAI 2015 pp. 234–241.

[2] Han, X. (2017), ‘MR-based synthetic CT generation using a deep convolutional neural network method’, Medical Physics 44(4), 1408–1419.

[3] Robertson et al, (2017) ‘Accurate simulation of transcranial ultrasound propagation for ultrasonic neuromodulation and stimulation." The Journal of the Acoustical Society of America 141(3), 1726-1738.