UBC Okanagan/Medical Physics

A Deep Learning Approach to RF Pulse Design for MRI

Seger C Nelson[1], Erin L MacMillan[2], Rebecca E Feldman[1,3]

Background

What is MRI?

- Medical imaging tool that uses radiofrequency (RF) pulses to excite protons to acquire a signal [1]
- RF pulses can be designed to acquire multiple slices simultaneously, without increasing the overall power deposition (SMS-PINS pulses) [2, 3]

What are the challenges with designing RF pulses?

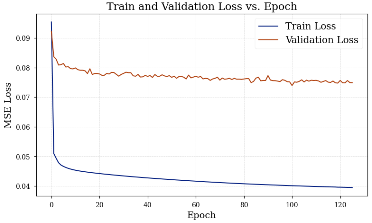
- Ill-defined
- Iterative
- Time-consuming
- In order to achieve a custom slice profile, one must first design an RF pulse [2-4].

What is the solution?

Use deep learning to reverse the process by training a model on a large dataset of RF pulse / slice profile pairs

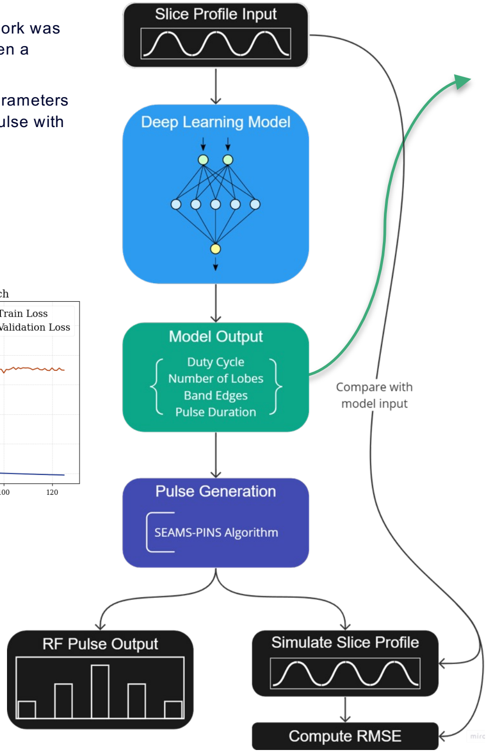
Methods

- A 5 layer forward-feed neural network was trained to classify an RF pulse given a custom slice profile input [5]
- Model outputs a combination of parameters that are used to simulate the RF pulse with the desired slice profile input:
  - Gradient duty cycle
  - Number of lobes
  - Band edges
  - Pulse Duration

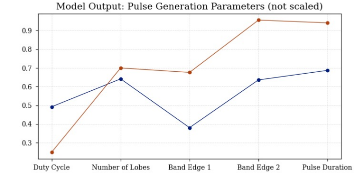


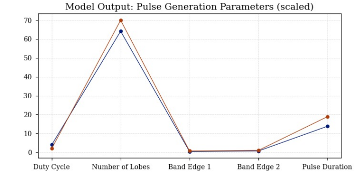
Training Parameters:

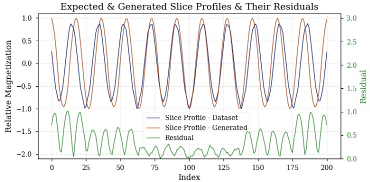
- Dataset size: ~550k
- Epochs: 125 (early stopping)
- Batch size: 32
- Learning rate: 1e-4
- Loss: Mean Squared Error
- Optimization: Adam
- Dropout

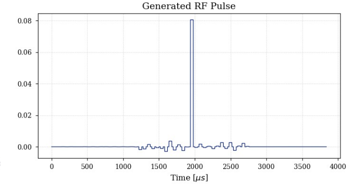


Results









Discussion

- RMSE was calculated over a smaller test set (computationally limited to n = 1000)
- Normalized Mean RMSE = 36.5%
- Visual inspection of the slice profiles results reveal significant variation

In Conclusion, this model serves as a proof of concept for the deep learning based design of RF pulses for MRI

Future Steps

- Investigate other deep learning models, expand dataset, introduce optimization loop following original prediction

References

1. Bushberg JT et. al, 2011.
2. Feldman RE et. al, Magn Reson Med. 2016.
3. Norris DG et. al, Magn Reson Med. 2011.
4. Balchandani P et. al, *Magn Reson Med*. 2010.
5. Paszke, Pytorch, 2023.

THE UNIVERSITY OF BRITISH COLUMBIA

Affiliations

[1]The University of British Columbia Okanagan, Dept of Computer Science, Math, Physics, and Statistics
[2]The University of British Columbia Vancouver, Dept. of Radiology
[3]Icahn School of Medicine at Mount Sinai, The BioMedical Engineering and Imaging Institute

We acknowledge the support of the Natural Sciences and Engineering Research Council of Canada (NSERC).