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Enhancing the speed and robustness of magnetic resonance imaging applications using deep learning

Steffen Bollmann

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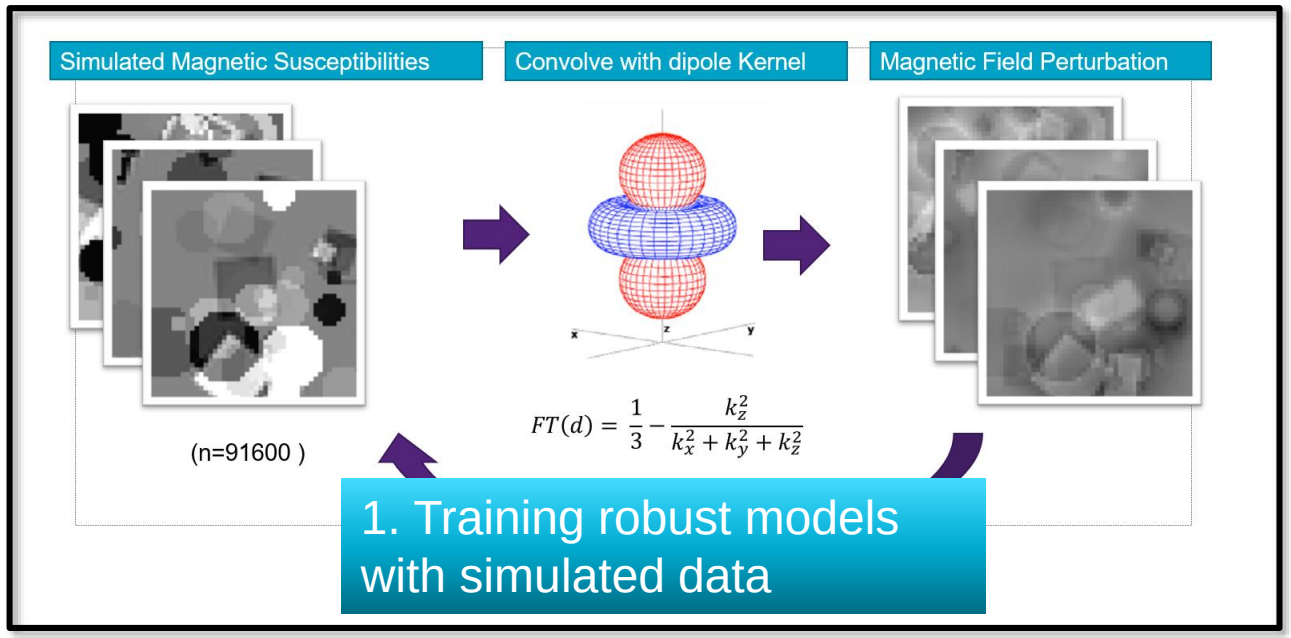
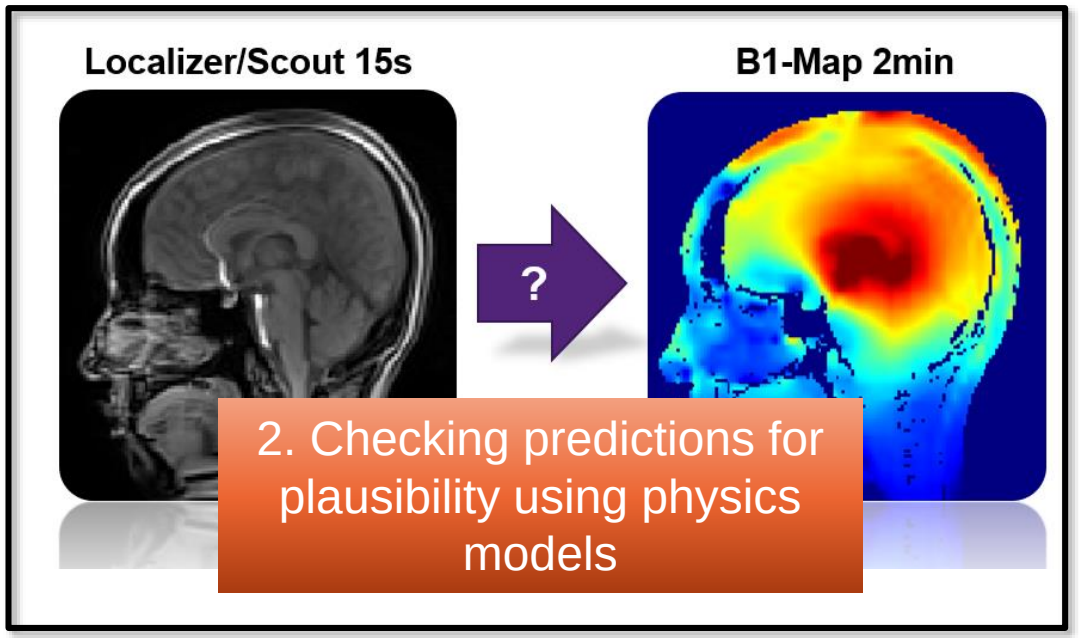
Affiliate Fellow – Centre for Advanced Imaging
CI - Centre for Innovation in Biomedical Imaging Technology
The University of Queensland, Australia

Centre for Innovation in Biomedical Imaging Technology
An ARC Industrial Transformation Training Centre

Content





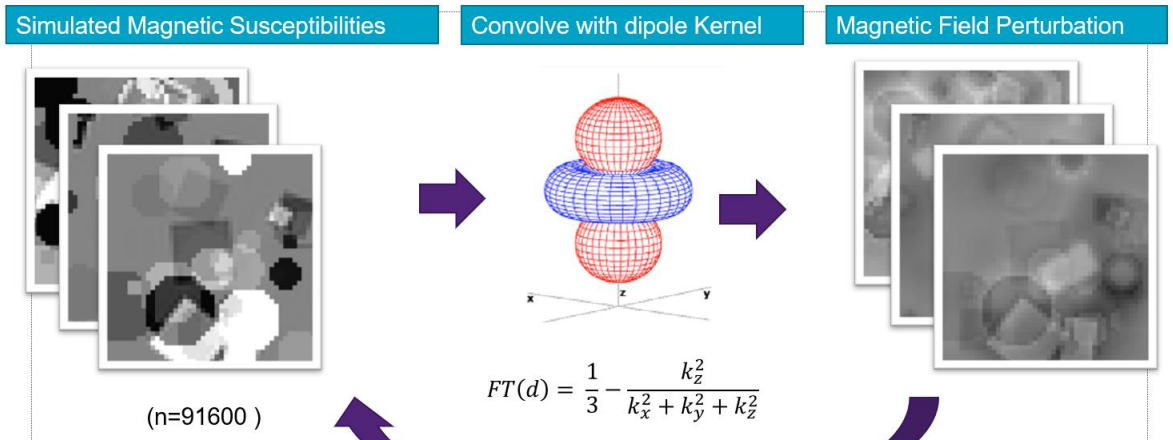
DATA AVAILABILITY STATEMENT

All data and code used in this paper can be found here:

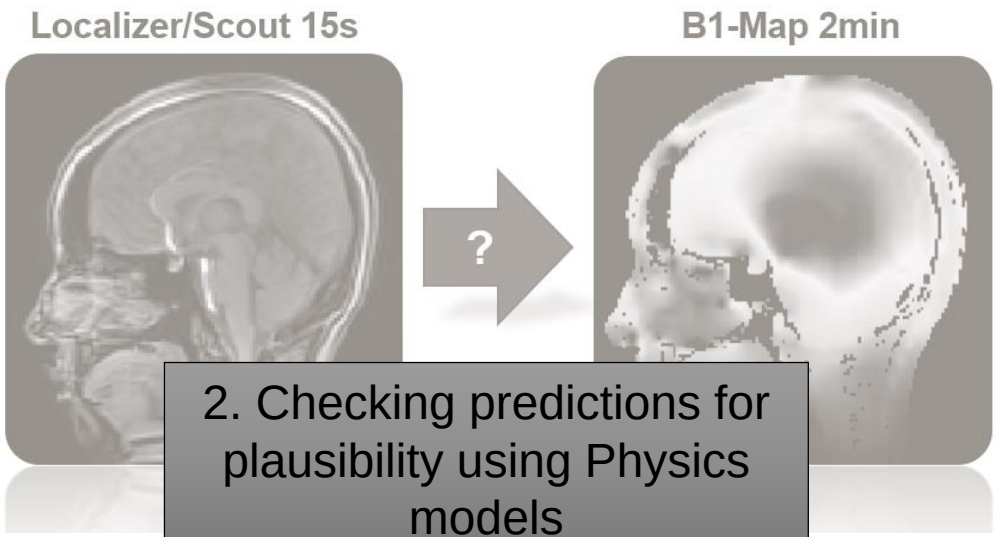
https://w v088e4iu/matlab_ zip?dl=0

3. Sharing deep learning models

Content



1. Training robust models with simulated data



2. Checking predictions for plausibility using Physics models

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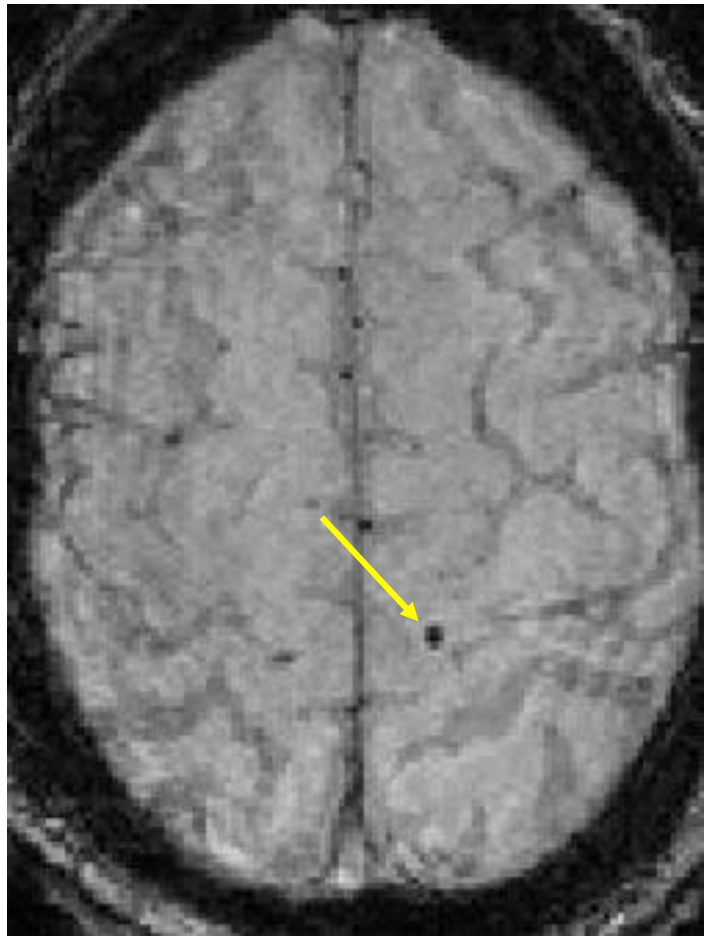
3. Sharing deep learning models

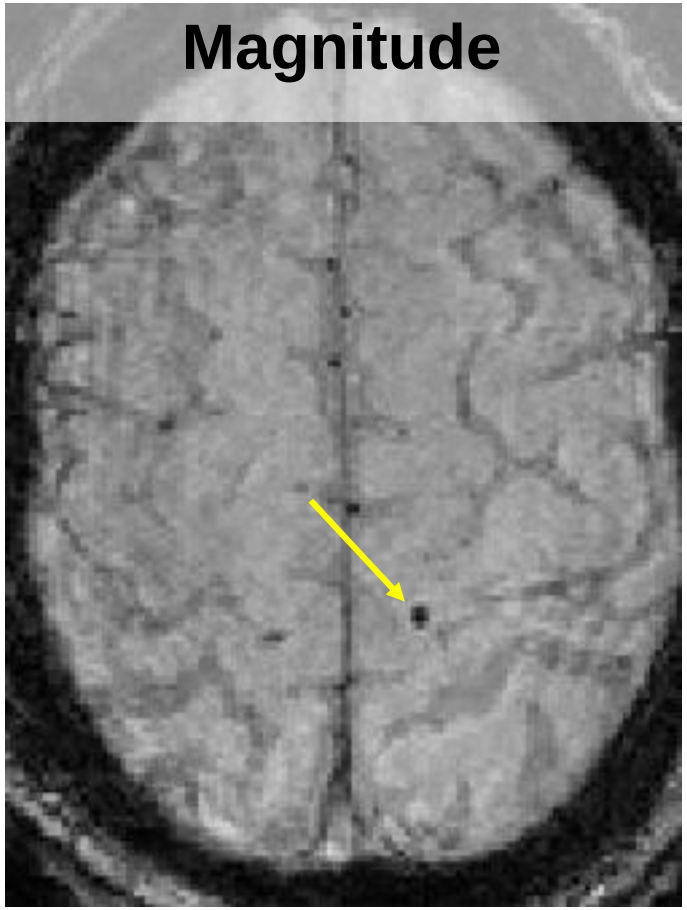
What is the scientific problem?

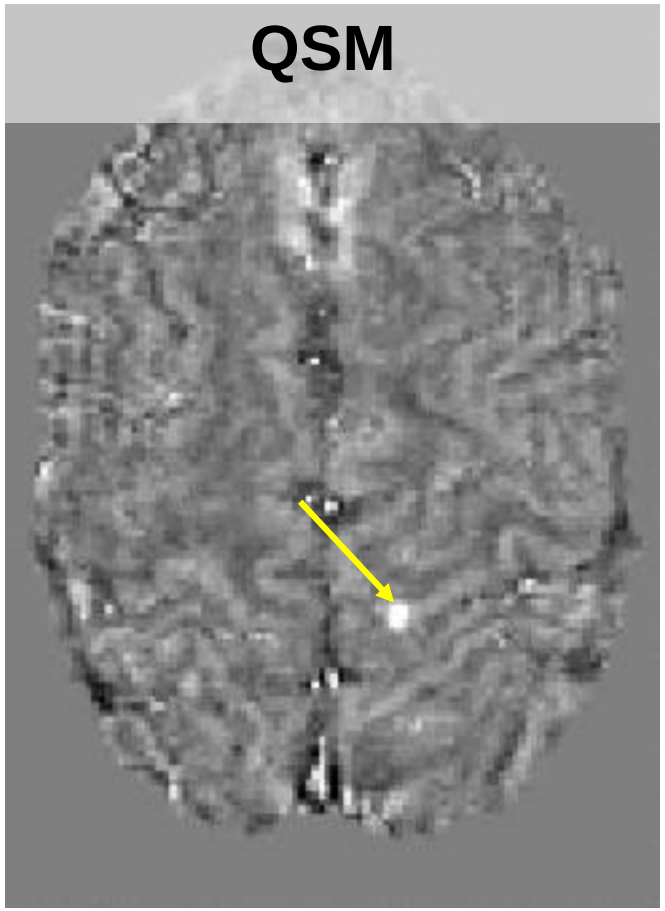
- Is this lesion calcified or bleeding?

- On a standard MRI scan we only see a black spot in both cases ☹



Quantitative susceptibility mapping (QSM) can help!

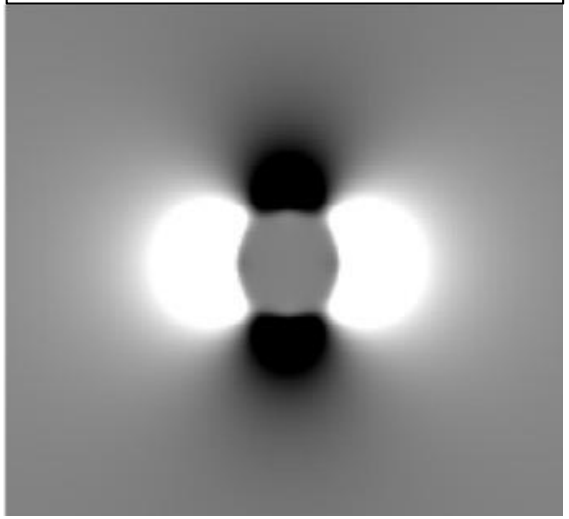




QSM differentiates between blood products (Hyperintense=white) and calcifications (Hypointense=black).

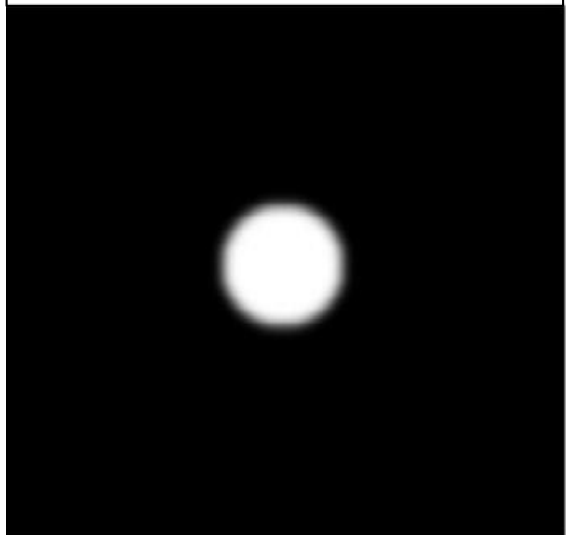
QSM Dipole inversion

field perturbation



Field-to-source inversion

magnetic susceptibility distribution



Forward Model

$$\Delta B_{\text{int}}(\vec{r}) = B_0 \cdot \int_{-\infty}^{\infty} \tilde{\chi}(\vec{r'}) \cdot d_z(\vec{r} - \vec{r'}) d^3\vec{r'}$$

Review: Deistung et al. NMR Biomed 2017; Schweser et al. Z Med Phys 2016

ELSEVIER

NeuroImage

Volume 195, 15 July 2019, Pages 373-383

DeepQSM - using deep learning to solve the dipole inversion for quantitative susceptibility mapping

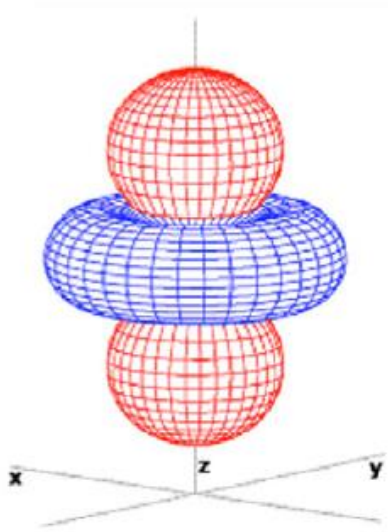
Steffen Bollmann [a], Kasper Gade Bøtker Rasmussen [b], Mads Kristensen [b], Rasmus Guldhammer Blendal [b], Lasse Riis Østergaard [b], Maciej Plocharski [b], Kieran O'Brien [a, c], Christian Langkammer [d], Andrew Janke [a, 1], Markus Barth [a, 1]

Generate data and train to solve inverse problem

Simulated Magnetic Susceptibilities

(n=91600)

Convolve with dipole Kernel

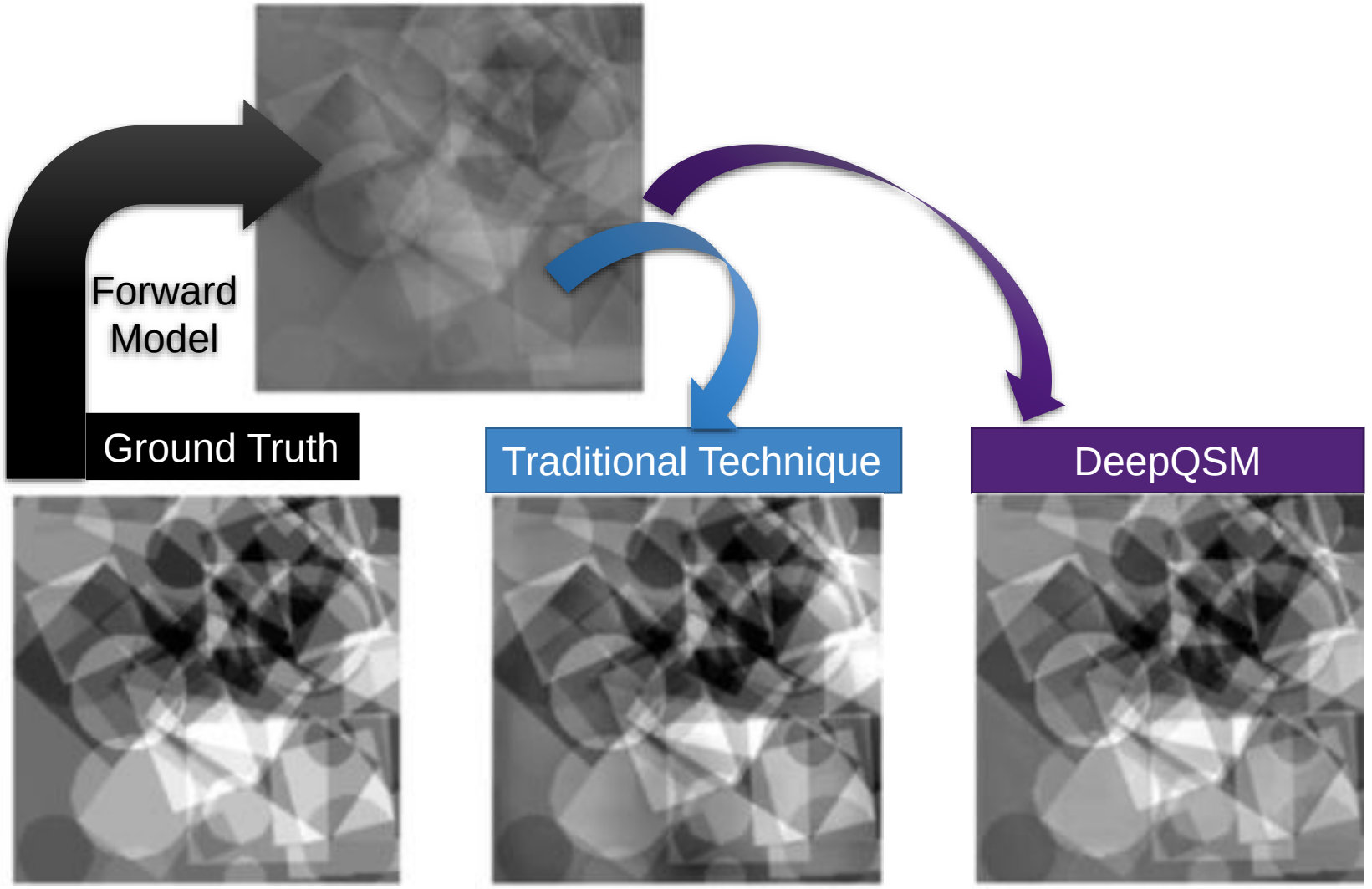


$$FT(d) = \frac{1}{3} - \frac{k_z^2}{k_x^2 + k_y^2 + k_z^2}$$

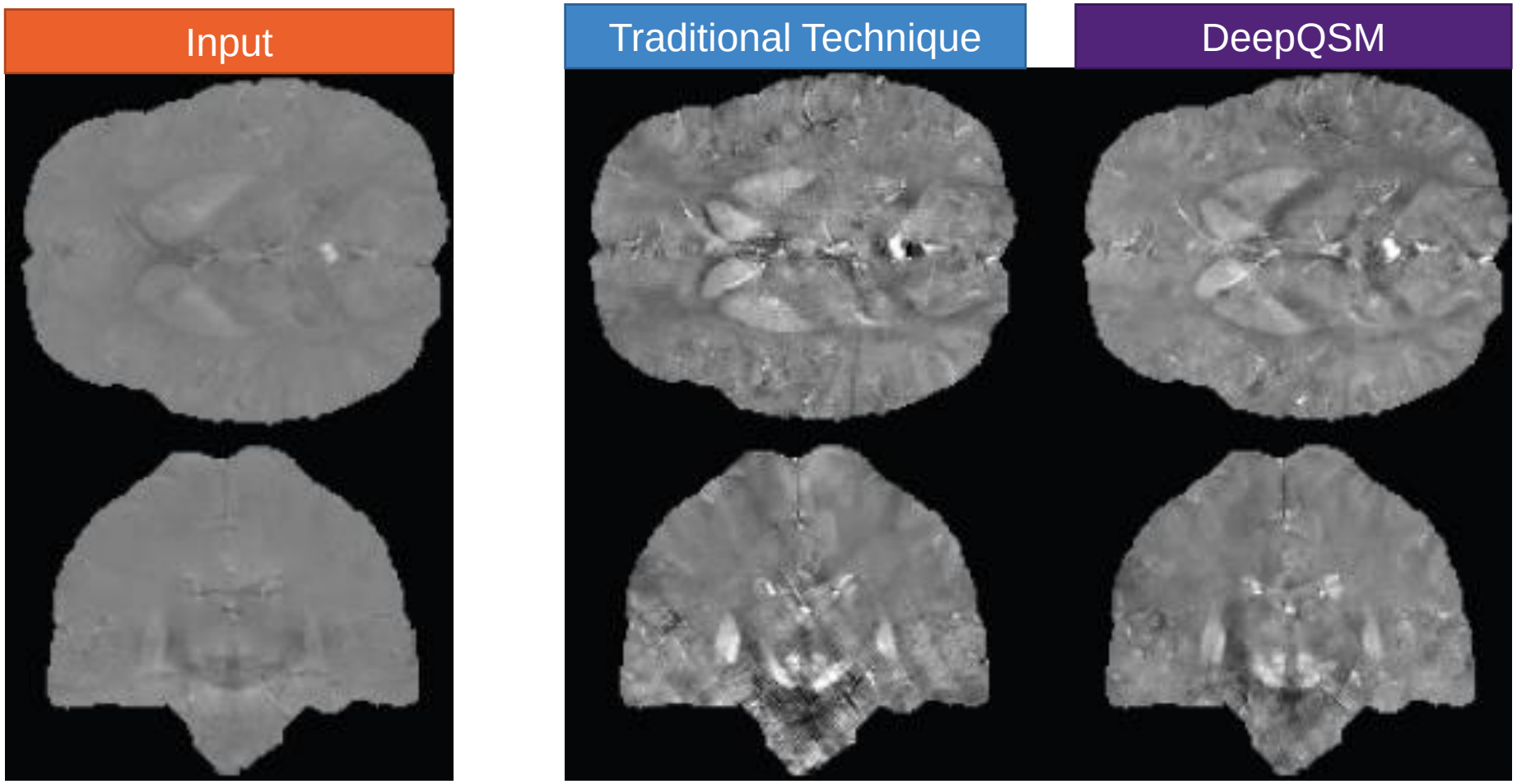
Magnetic Field Perturbation

TRAIN

Test on simple shapes – similar to training data

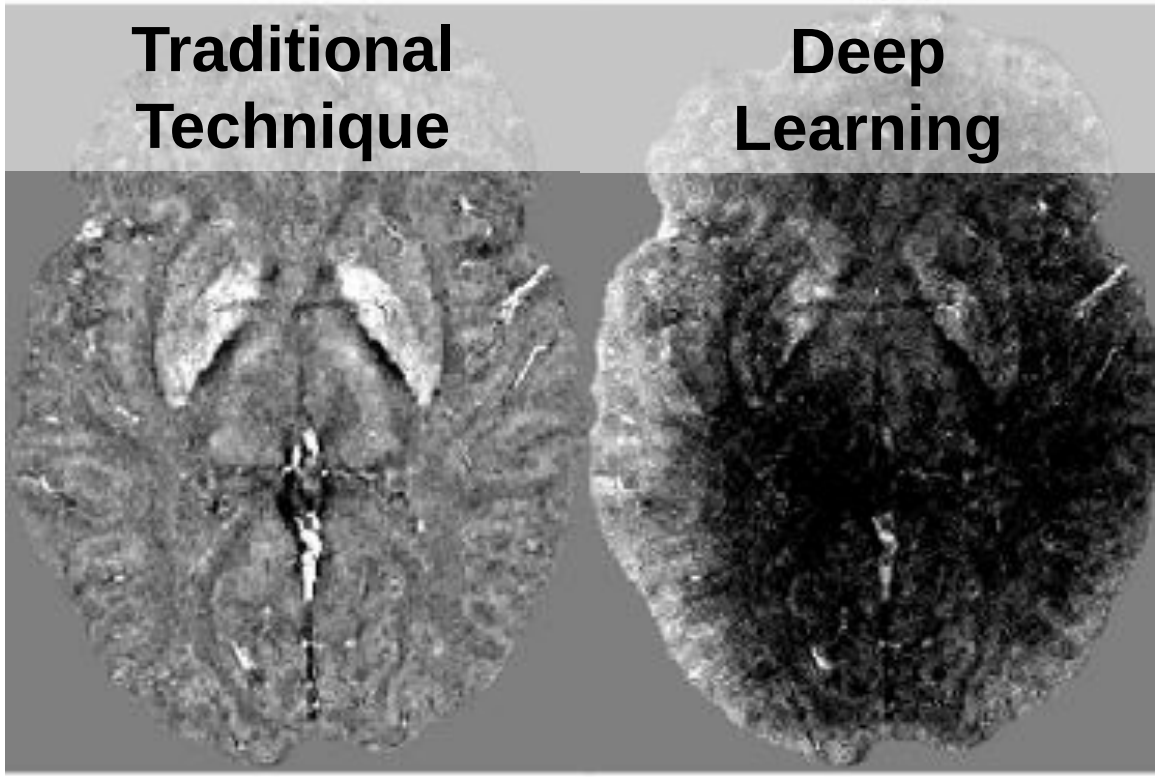


Generalizes to in vivo brain data ☺

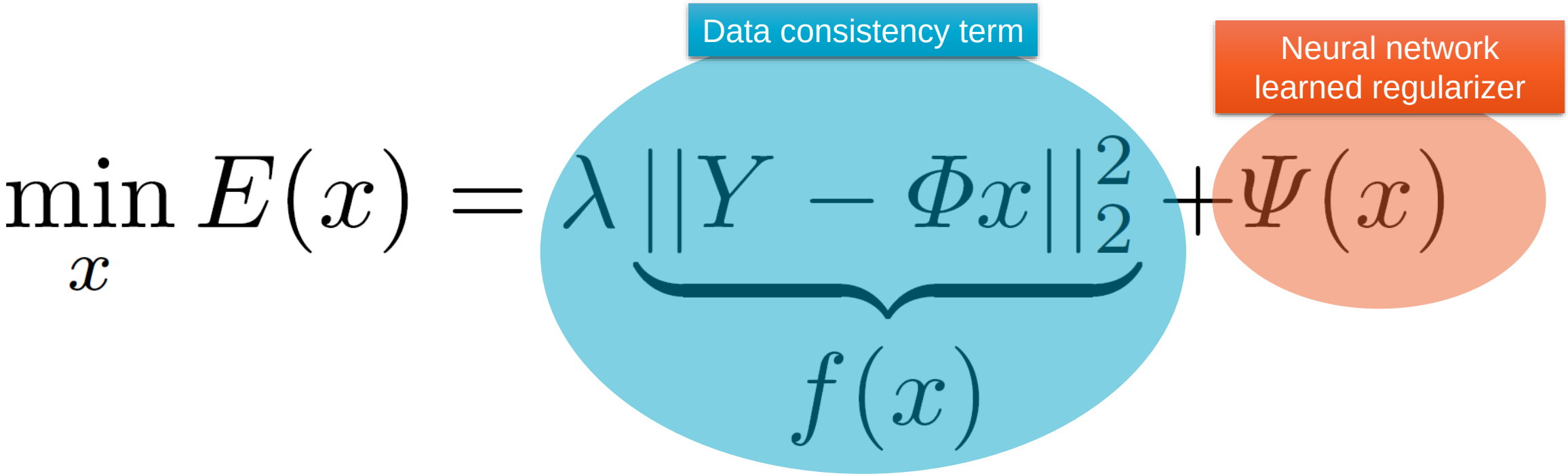


Problem: Sensitivity to input data distribution

Adding noise to the input data leads to failure of network prediction



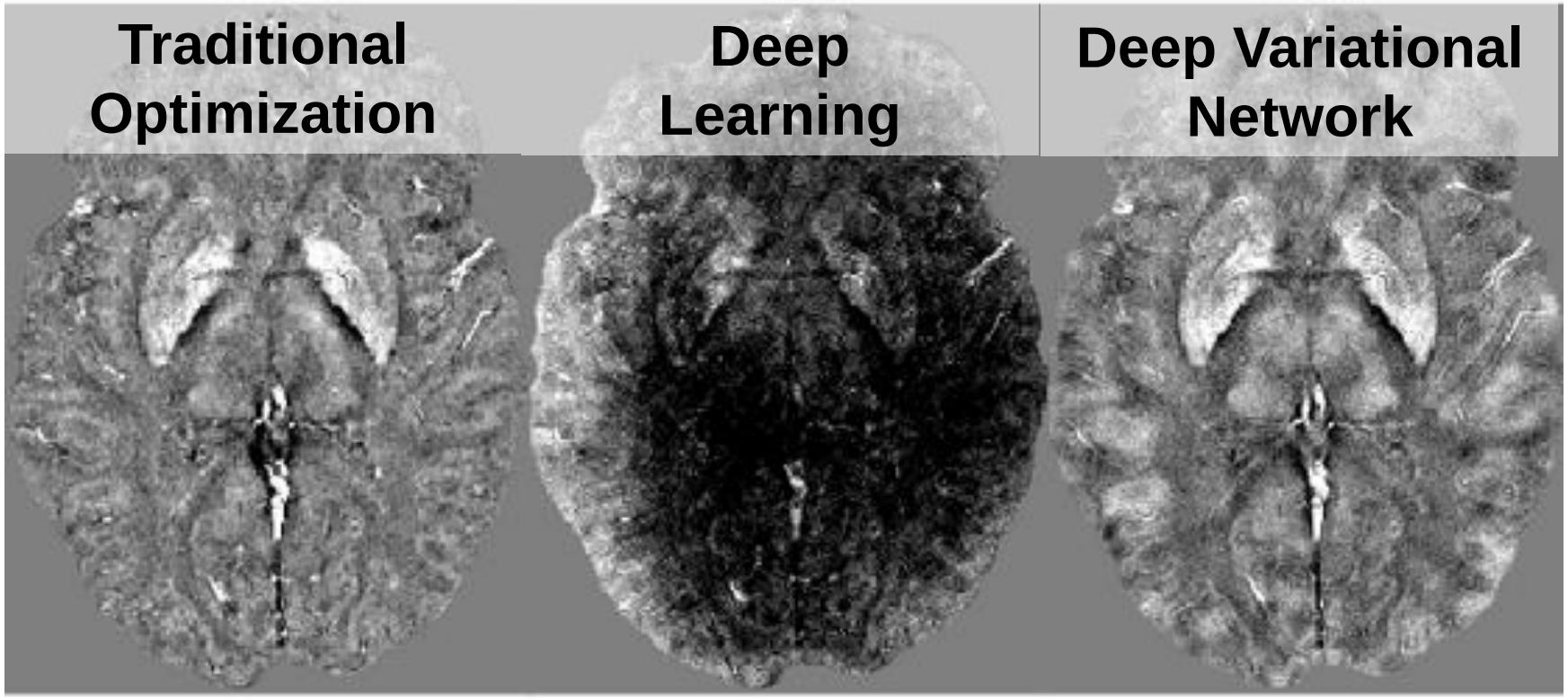
Variational Network: Combine traditional optimization + DL



Cognolato et al. in preparation

Robustness to noise due to data consistency constrain:

Adding noise to the input data



Cognolato et al. in preparation

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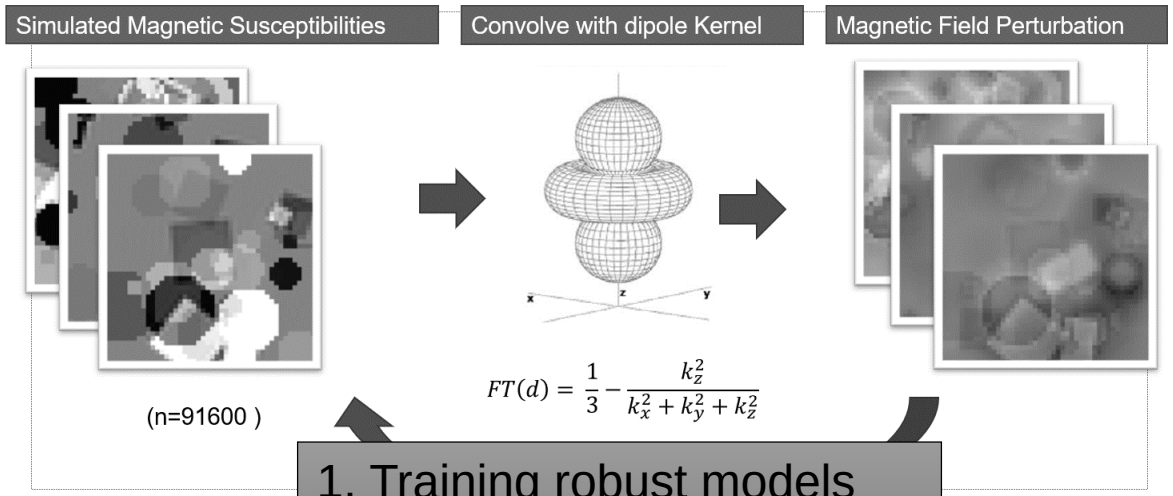

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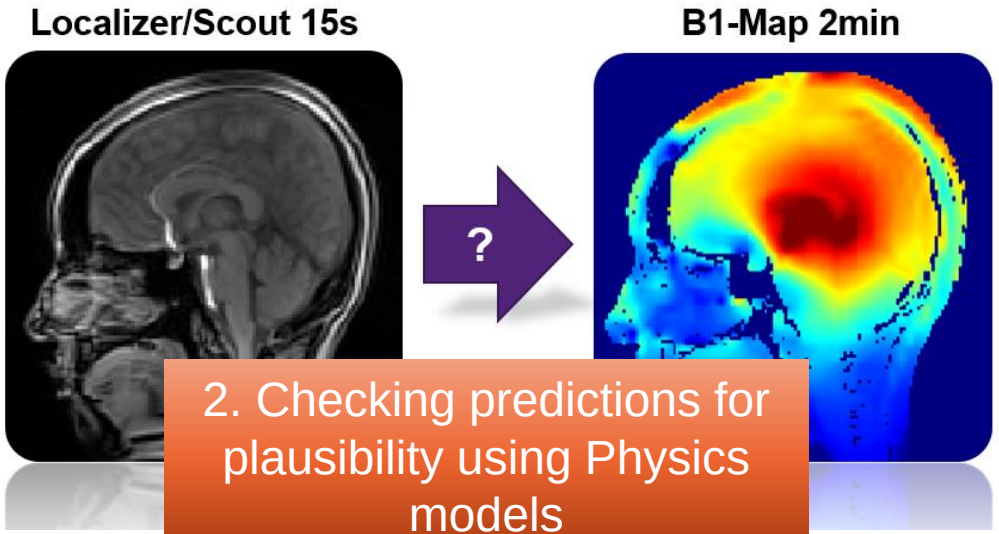

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3. Sharing deep learning models

MAGNETIC RESONANCE IN MEDICINE

ISMRM

ONE COMMUNITY FOR CLINICIANS AND SCIENTISTS

FULL PAPER

Improving FLAIR SAR efficiency at 7T by adaptive tailoring of adiabatic pulse power through deep learning B_1^+ estimation

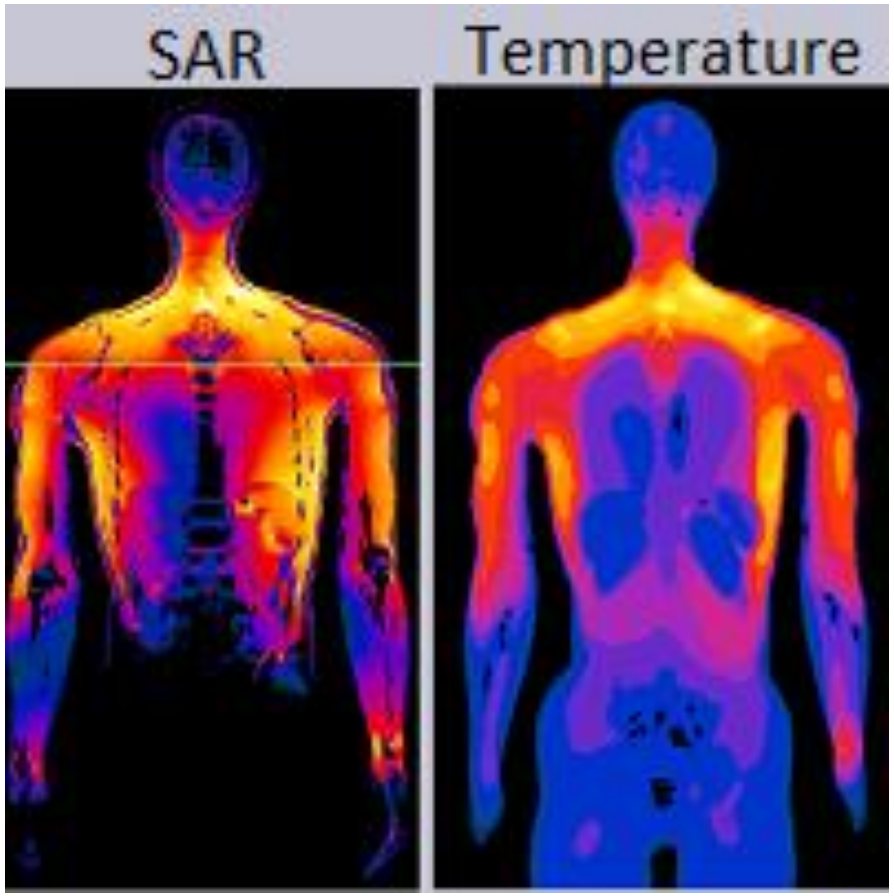
Shahrokh Abbasi-Rad ✉, Kieran O'Brien, Samuel Kelly, Viktor Vegh, Anders Rodell, Yasvir Tesiram, Jin Jin, Markus Barth, Steffen Bollmann

First published: 23 November 2020 | https://doi.org/10.1002/mrm.28590

Background and Motivation

In MRI we are limited by the **Specific Absorption Rate (**SAR)

scans take longer to limit heating effects



https://itis.swiss/customized-research/mri-safety-evaluation/

Background and Motivation

- with *a-priori* knowledge of the 3D B1 field, SAR could be reduced by saving SAR where we don't need it

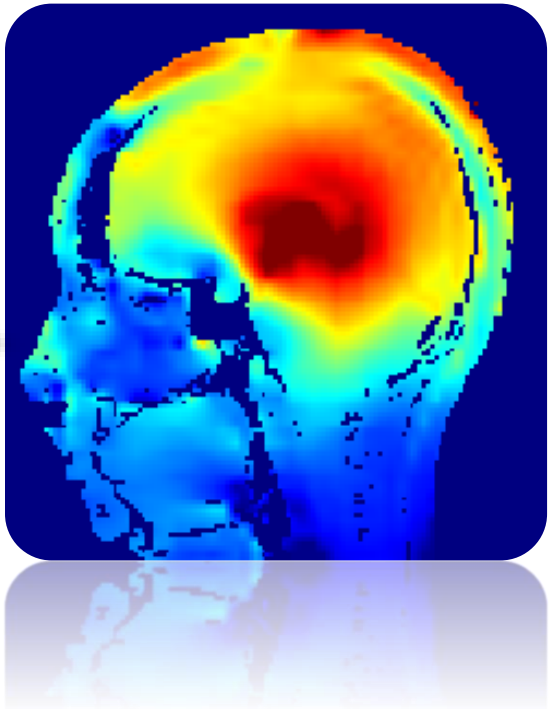
- But: B1-map requires additional scan time (~ 2min)

- Can we predict an approximate B1-map from the localizer scan's B1 artifact?

Localizer/Scout 15s

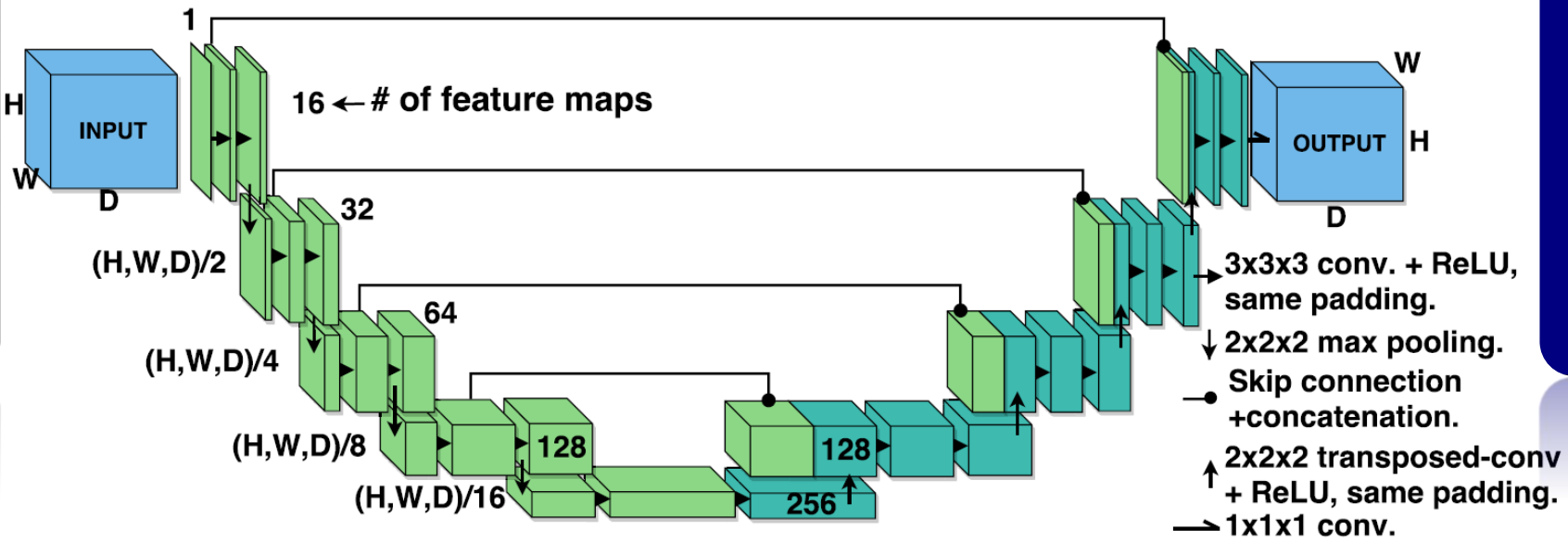
?

B1-Map 2min

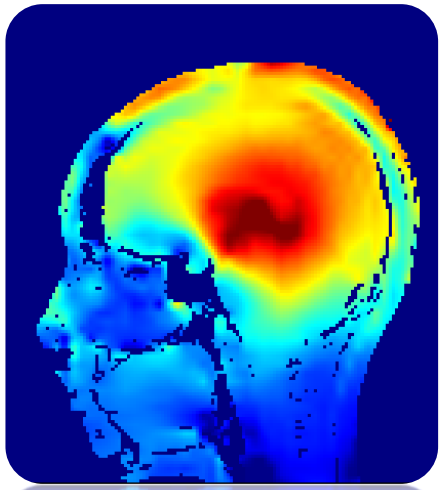


Methods

15s Localizer/Scout



2min B1-Map



Train Data: 7000 pairs of patches
Test Data: 1000 pairs of patches
Epochs: 200
Learning rate: 0.02

Results

15s Localizer
(Input to Network)

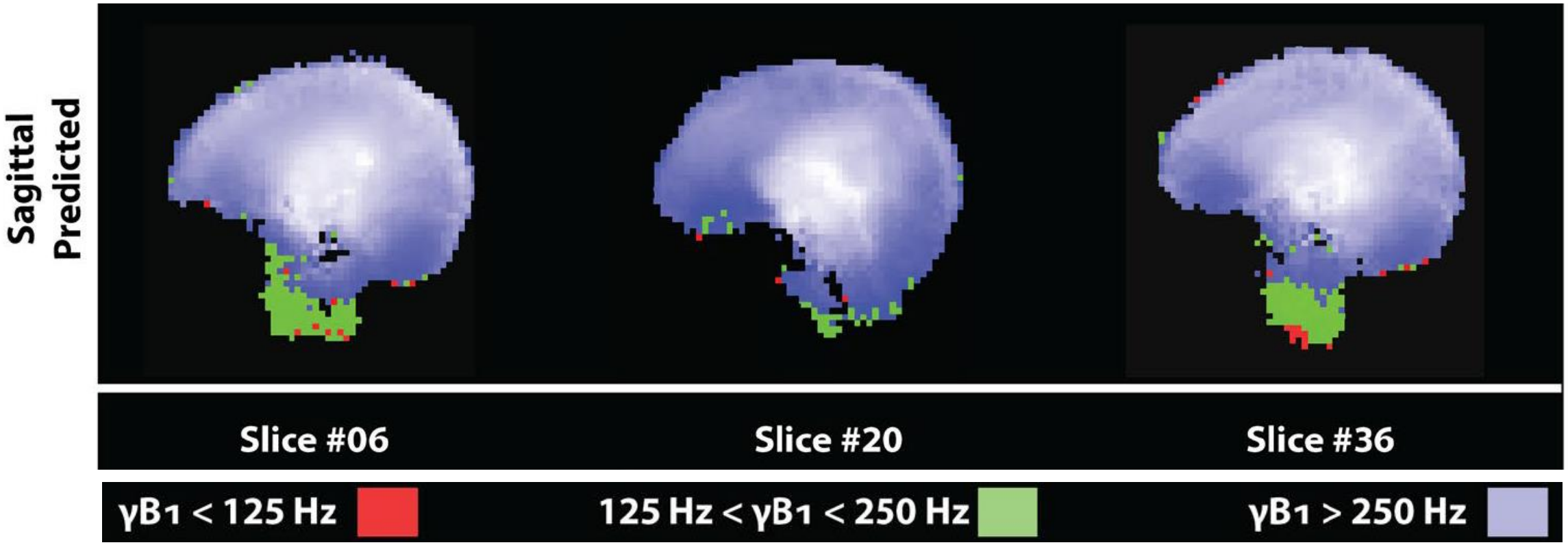
2min B1 Map
(What we tried to learn)

0s predicted B1 Map
(What the network predicts)

not perfect, but good enough - 5 % error

Don’t trust a prediction you haven’t checked yourself…

We check if the prediction delivers good results in practice using the underlying physics relationship:

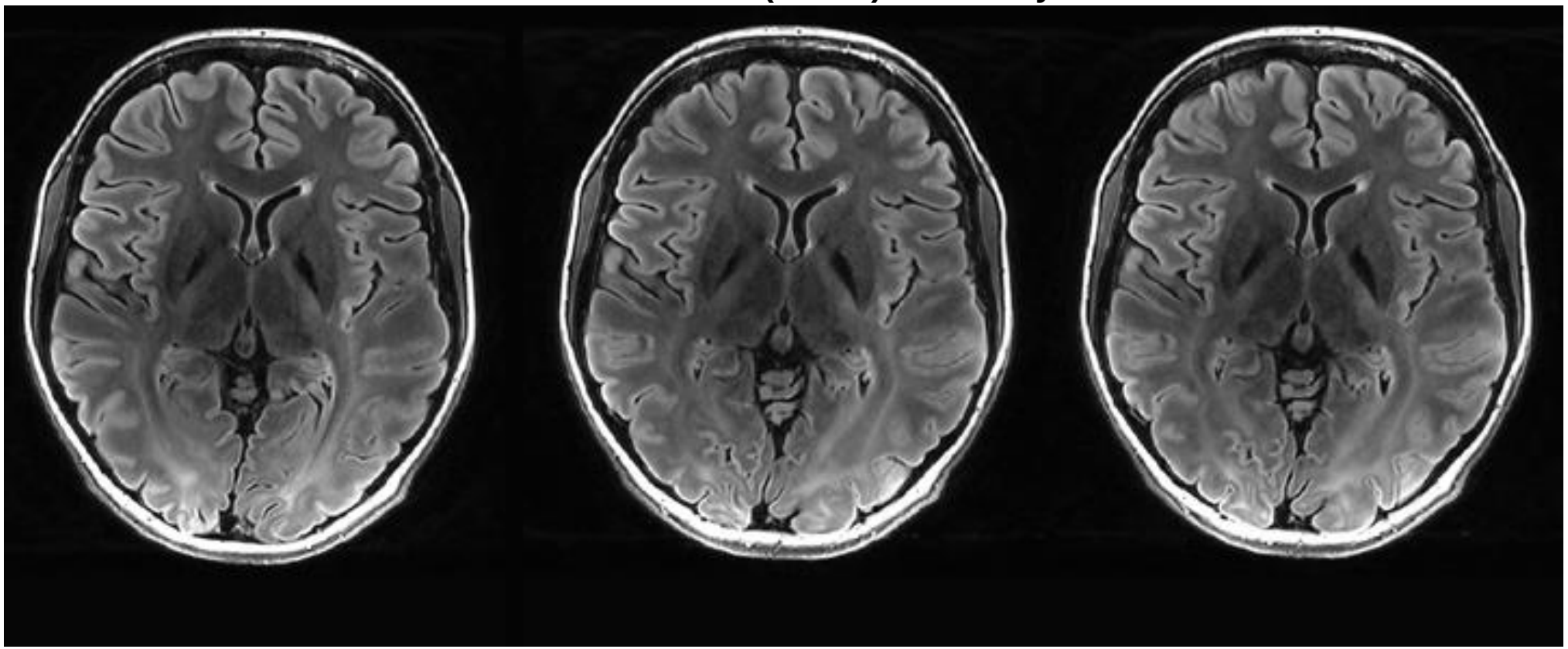


SAR Reduction Experiment

3 min 18 sec (FLAIR) + 1min 31 sec (Delay)

2 min (B1 map) + 3 min 18 sec (FLAIR) + 0s Delay

3 min 18 sec (FLAIR)

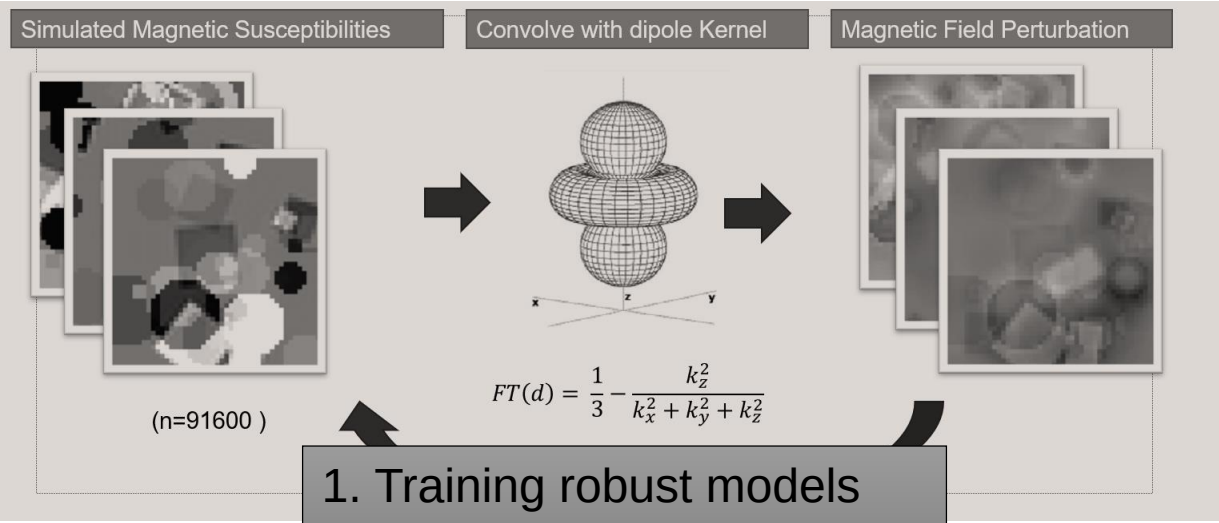


Non-Scaled (SAR = 140%)

Scaled (Measured) (SAR = 97%)

Scaled (CNN) (SAR = 97%)

Content



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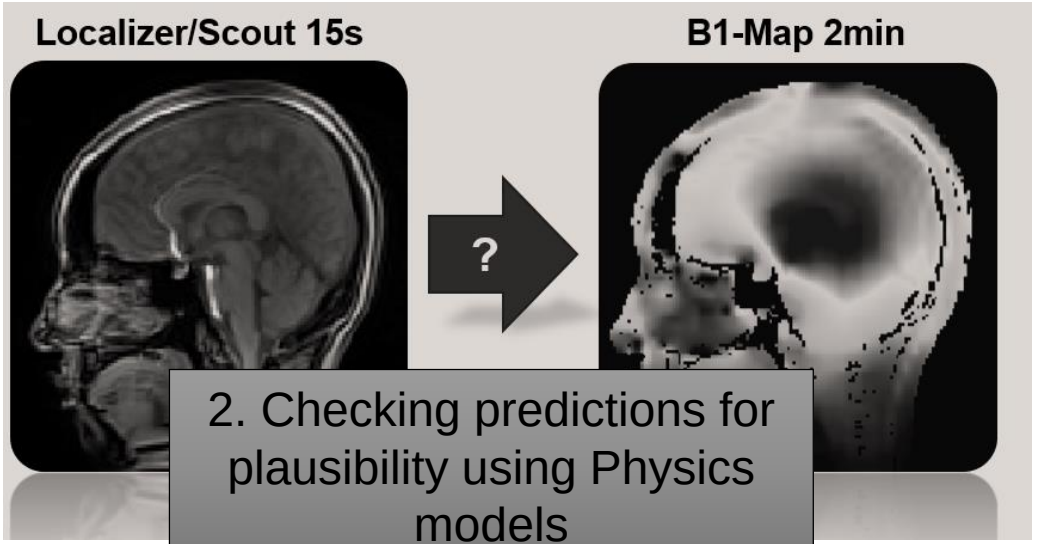

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3. Sharing deep learning models

Problem: Sharing models and code with readers

Why?

- Reviewers are sceptical about deep learning and would like to understand why it works and when it fails

- Readers of the paper should be able to reproduce the results in the paper and modify the presented concepts

BUT:

- Deep learning toolkits not easy to install and require GPUs …

Open Science is easy, right?

What if this free service stops?

Download 2GB file just to see which functions were used?

DATA AVAILABILITY STATEMENT

All data and code used in this paper can be found here: https://www.dropbox.com/s/ijkxmopv088e4iu/matlab_code_data_mri_paper2021.zip?dl=0

Will the code still work in the next version? Does the reader have a matlab license?

I found a bug and need to update this ….

Open Science is easy, right?

Data upload via command line.

OSF

osfclient

DATA AVAILABILITY STATEMENT

We facilitate the reproducibility of our study by providing an interactive version of our implementation on a publicly accessible cloud-based platform. The readers can explore the implementation of the model (neural network), train the model with different hyper-parameters and architectures, investigate the stability of the training process, and reproduce our results with the identical model used in this manuscript (https://github.com/sbollmannMRI/scout2B1, 320a6ab). We anonymized and stored the input data (localizer, SA2RAGE B_1^+) of 28 participants in OSF (OSF, Center for Open Science, Inc., Virginia, USA) accessible via https://osf.io/y5cq9/.

Open Science is easy, right?

Data download within Jupyter notebook.

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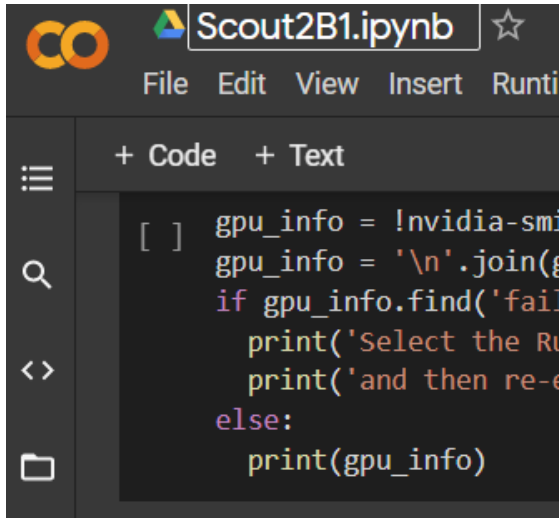

Open Science is easy, right?

Provide source code in an easy accessible way

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This commit was used for the paper, but bug fixes possible

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Creating snapshots for version control.

Open Science is easy, right?

Interactively running in browser – no setup needed

Platform can be changed: link in OSF

Provide source code in an easy accessible way

This commit was used for the paper, but bug fixes possible

Data and links can be updated if bugs found or services move

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MRM Society Journal Highlight

https://blog.ismrm.org/2021/04/30/reproducible-research-insights-with-shahrokh-abbasi%E2%80%90rad-markus-barth-and-steffen-bollmann/

Thank you

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