Artificial
Intelligence in
Medicine

A Machine Learning Approach to Quantitative Susceptibility Mapping

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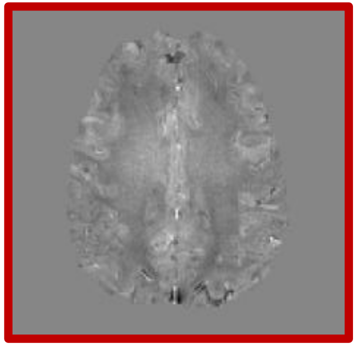
A Machine Learning Approach to QSM: intro

QSM: $\phi(r) \rightarrow \chi(r)$
Ill-posed problem: singularities in k-space

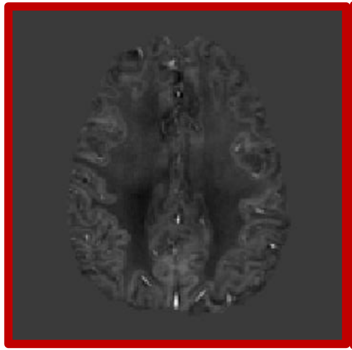
From Phase – map **To Susceptibility – map**

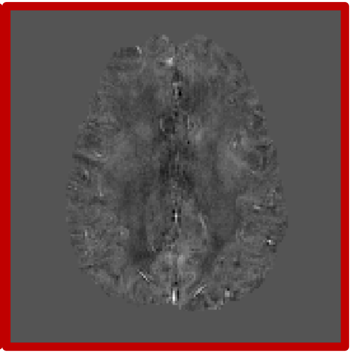


Multiple-orientation approaches

COSMOS
(Calculation Of Susceptibility through Multiple Orientation Sampling)

- Multiple head-orientation acquisition
- Long acquisition time
- Uncomfortable for the patient
- Accurate and precise reconstruction





Single-orientation approaches

TKD , iLSQR
(Truncated K-space Division)

- Single head-orientation acquisition
- Short acquisition time
- Numerical strategies (inverse filtering or iterative methods)
- Noisy reconstruction

QSM with CNNs: first application

For QSM in the clinical area

We need accurate and fast reconstruction

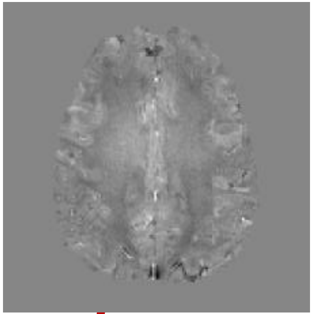
→ **Convolutional Neural Networks (CNNs)**

Deep learning tool in image processing
Image reconstruction task
Supervised Learning

Database from QSM2016 Challenge

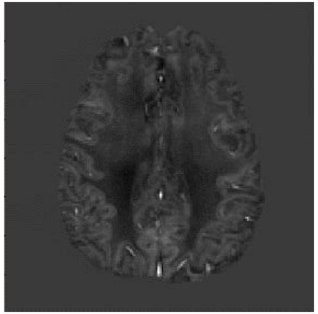
- One subject
- 12 head orientations
- 3D GRE images
- 3T – Siemens
- # pixels: (160,160,160)
- Resolution: [1.06, 1.06, 1.07] mm
- FOV : (17, 17, 17) cm
- TE/TR = 25/35 ms

INPUT



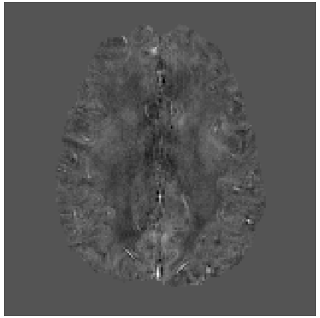
ϕ-map

REFERENCE



COSMOS

CONTROL



TKD

OUTPUT

?

2D- NET

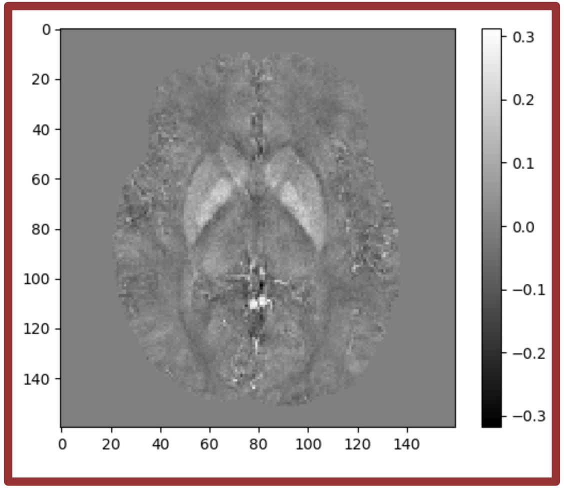
χ-map

QSM with CNNs: results

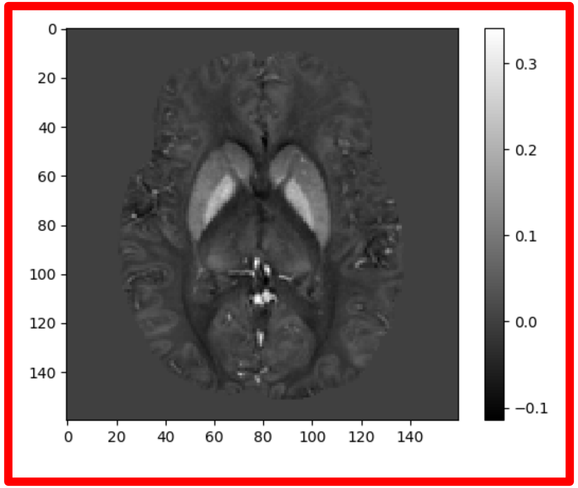
- Input data: pre-processed phase data of one volunteer
- Input data with $\vec{z}$ directed along $\overrightarrow{B_0}$ direction
- COSMOS map used as label

- Computational details: Keras 2.2.0, Tensorflow 1.9.0 Backend, Python 3.6 GPU nVidia Titanum XP, Cuda 9.0
- Data augmentation: 2D patches, 4 level of depth,15.6 h training time

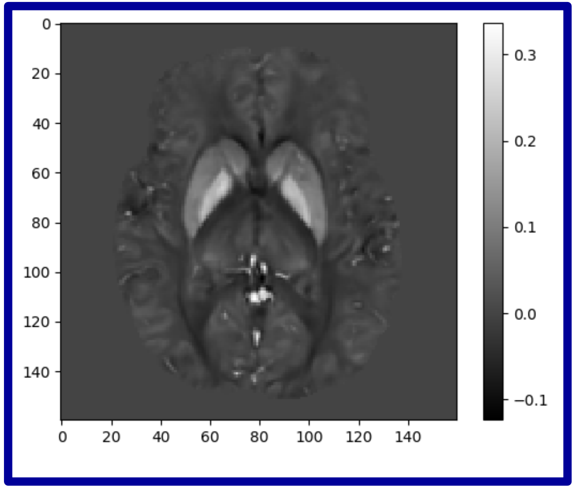
TKD (ppm)



COSMOS (ppm)

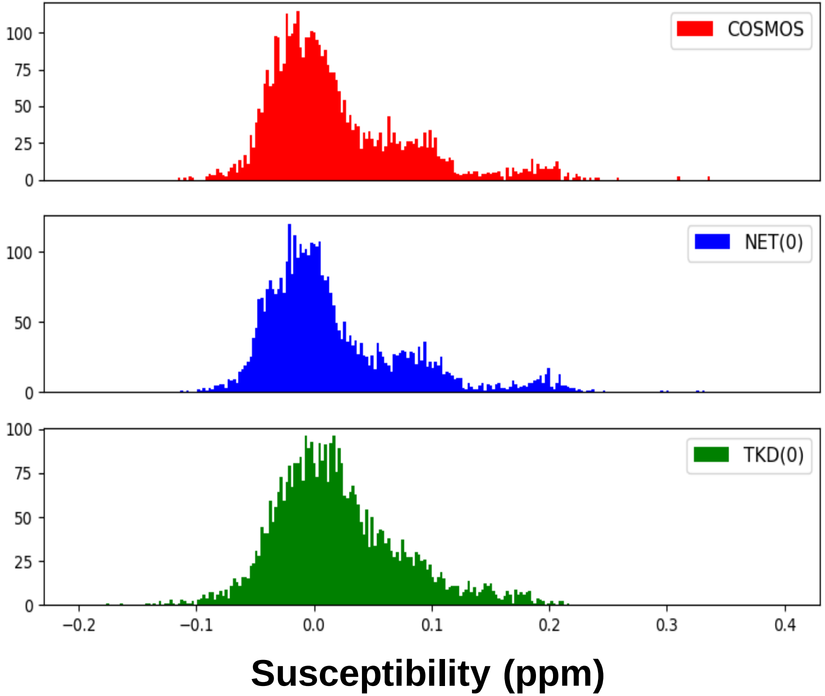


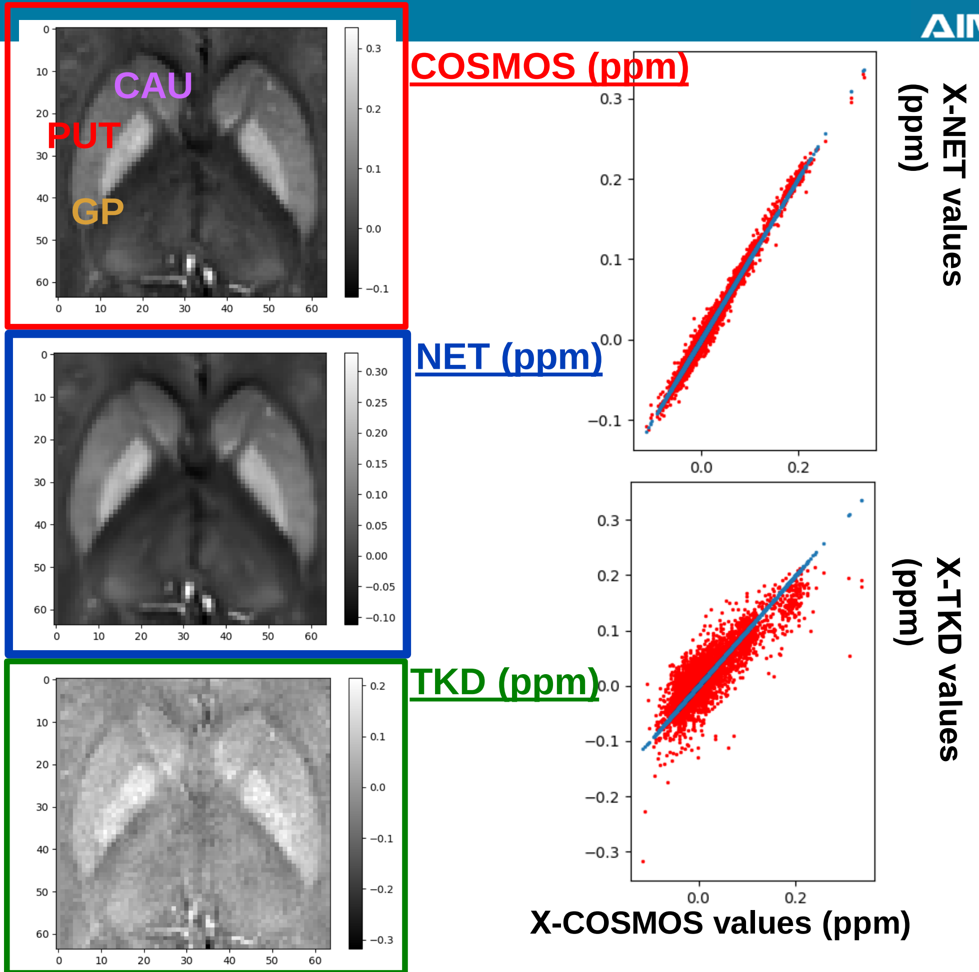
NET (ppm)



QSM with CNNs: results

Intensity Histogram and Scatter Plot





QSM with CNNs: second application

To test the generalizability of the model

We applied the 2D-NN for different type of data

The Reference was COSMOS as multiple orientation approach

- Data augmentation: 2D patches; Architecture: 4 level of depth. 8 h training time

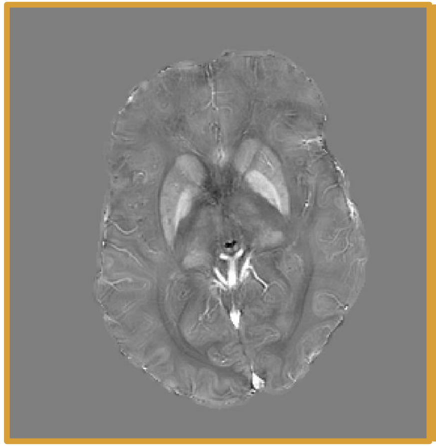
Subject database

6 subjects
Scanner: Achieva, Philips
$B_0 = 3T$
Resolution = [0.8 0.8 3] mm
TE1 = 9.4 ms
TE2 = 20 ms
6 head orientations for each subject

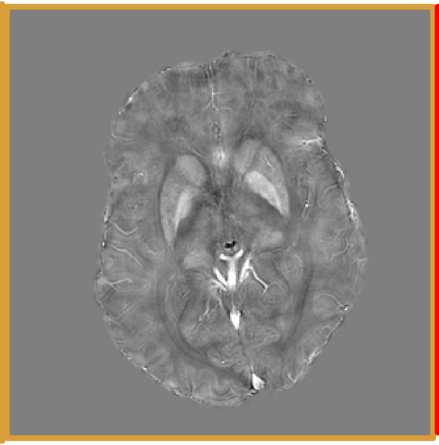
- Subjects 2,4,5,6 were used during the training
- The trained model was tested on subj2 and subj7 (the latter not used during the training)

QSM with CNNs second application: results

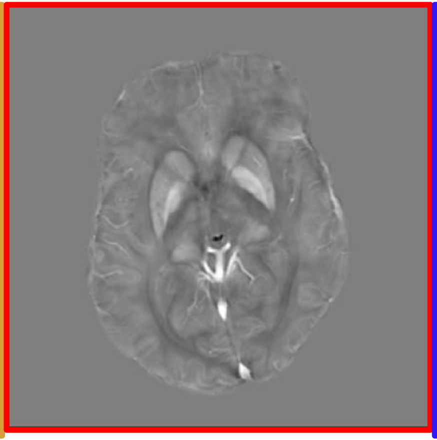
2D training, using COSMOS map as label



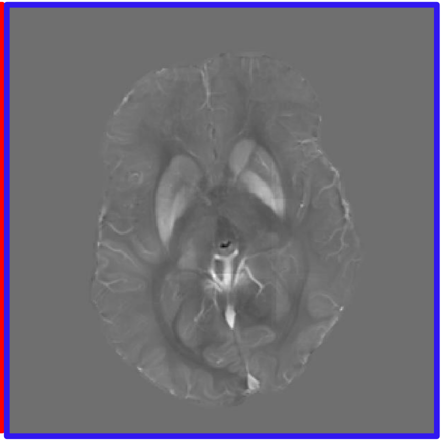
iLSQR



TKD



COSMOS

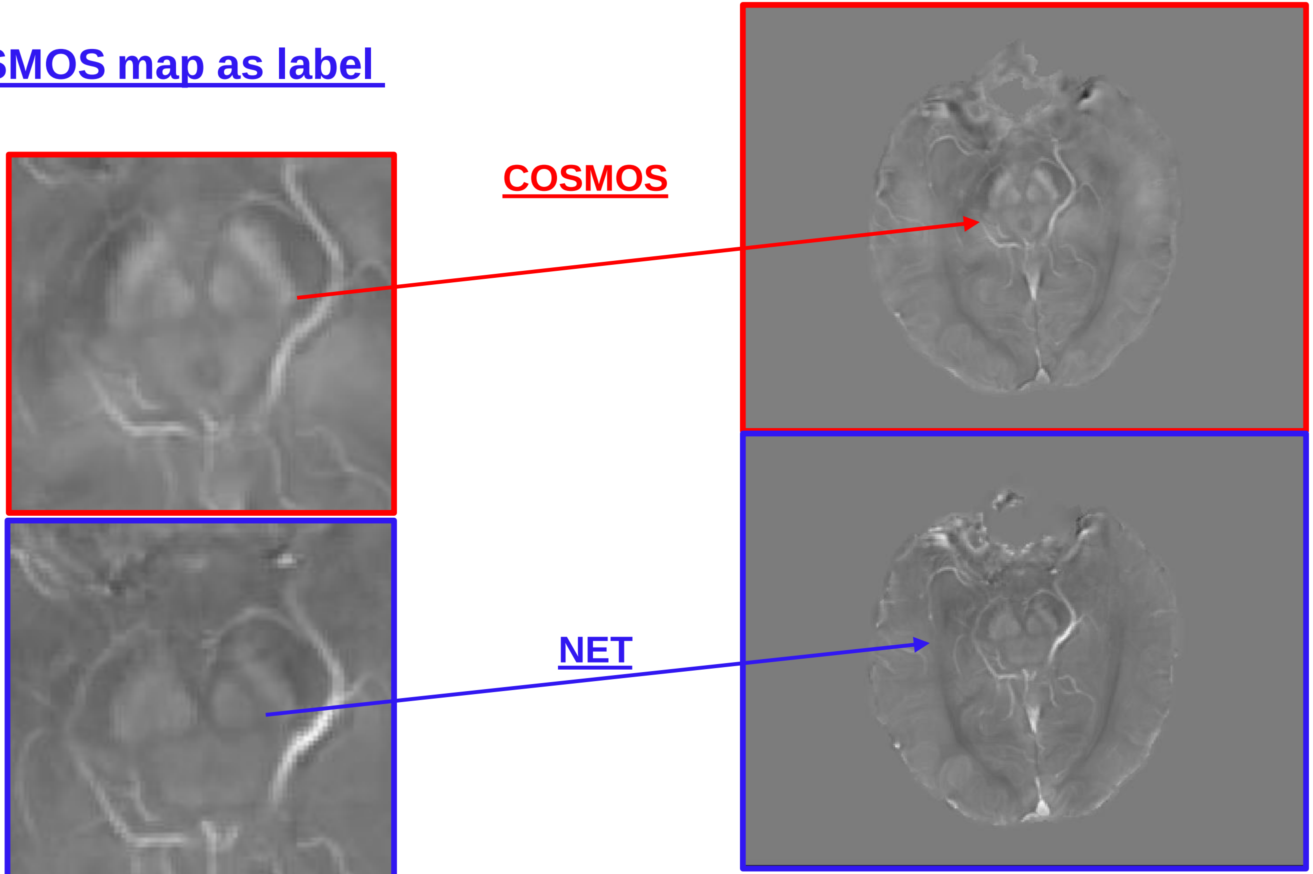


NET

Subj 2, used during the training

QSM with CNNs second application: results

2D training, using COSMOS map as label



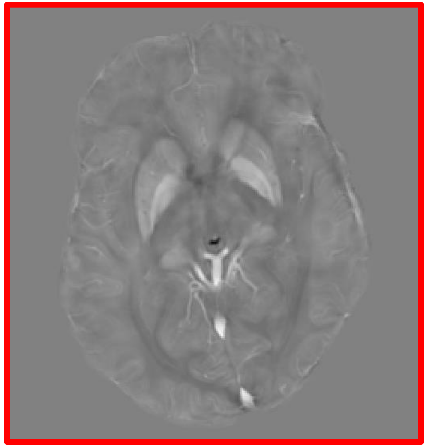
Subj 7
Not used during the training

QSM with CNNs 2.0

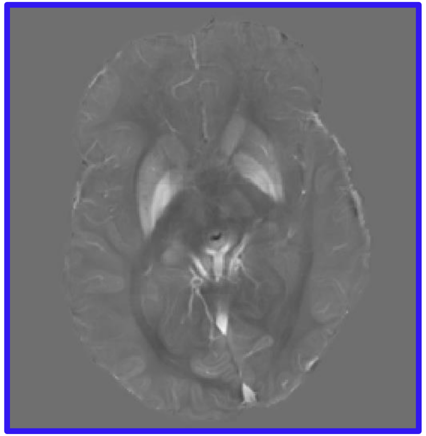
3D training, using COSMOS map as label

- 3D patches
- Data augmentation: 3D patches; Architecture: 4 level of depth. 15 h training time

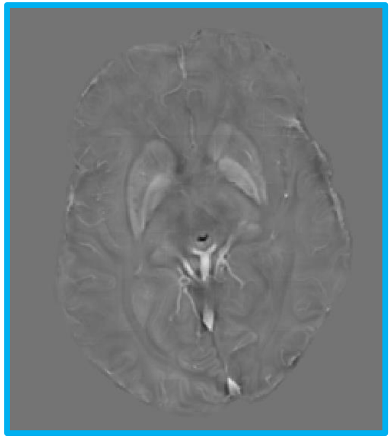
Subj 2



COSMOS



NET 2D



NET 3D

Larger training size needed:

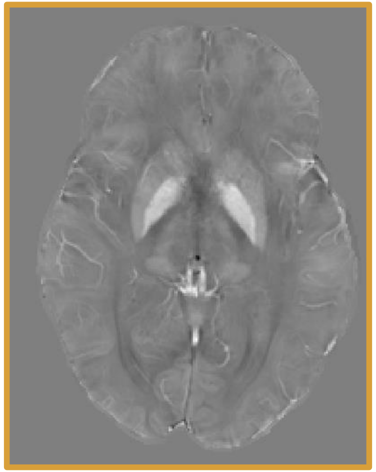
new GPU TESLA M10 (AIM funding) embedded in a server at the University of Bologna, Department of Physics

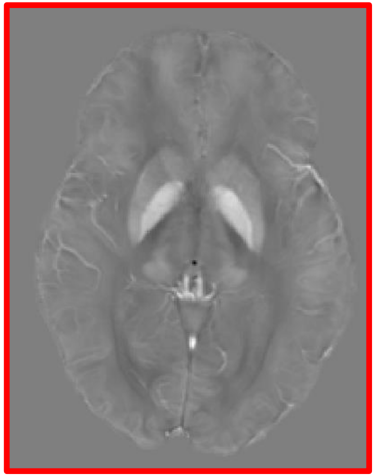
UNDER TESTING

QSM with CNNs 2.0

Issues:

- Is COSMOS the right reference? Effect of the registration with non uniform resolution (the coarsest resolution is not always along the same direction with respect to the frame)
- effect of the added thresholding operation in performing the COSMOS algorithm.





iLSQR

COSMOS

Acquisition Details

Scanner: Achieva, Philips
B = 3T
Resolution = [0.8 0.8 3] mm
TE1 = 9.4 ms
TE2 = 20 ms

QSM with CNNs 2.0: NEXT

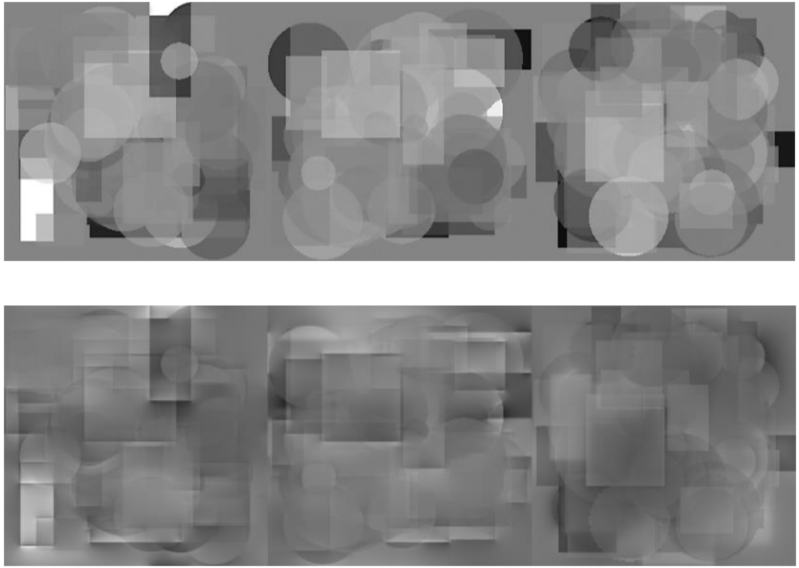
Future works:

- 3D training, working with synthetic images
  - **Simulate susceptibility data $\chi(r)$** and reproduce the field perturbation $\Delta B(r)$ ones using:

$$\frac{\Delta B(r)}{B_0} = F^{-1}(\chi(k) \cdot K(k))$$

Simulated data:
20 images with size [288 288 288].
Each of them was filled with 100 spheres and 100 rectangles. To each sphere and rectangle, a uniform values of susceptibility is assigned

SIMULATED SUSCEPTIBILITY MAP $\chi(\boldsymbol{r})$



EVALUATED FIELD PERTURBATION MAP $\frac{\Delta B(\boldsymbol{r})}{B_0}$

Once trained the NNs we will test the net first on other synthetic data and then on in vivo data

thank you