BrainWatchers

Capstone Project presentation

08.09.2022

The BrainWatcher's team

Leonardo Ranasinghe

Physicist

Tamara Pallien

Biologist
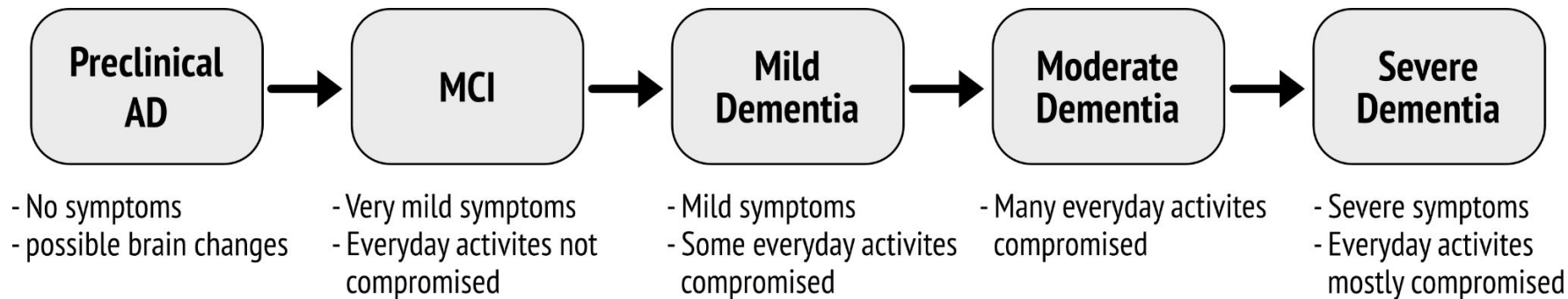
Dennis Eickhorn

Mathematician

Valentin Schoop

Biochemist

Introduction - Alzheimer's disease (AD)

- progressive brain disease
- Symptoms: apathy, depression, disorientation, behavioural changes

Preclinical AD	→	**MCI**	→	**Mild Dementia**	→	**Moderate Dementia**	→	**Severe Dementia**
- No symptoms - possible brain changes		- Very mild symptoms - Everyday activites not compromised		- Mild symptoms - Some everyday activites compromised		- Many everyday activites compromised		- Severe symptoms - Everyday activites mostly compromised

MCI - mild cognitive impairment

Diagnosis of Alzheimer's disease

Some common diagnostic methods include:

- Cognitive assessment test (e.g. MMSE) (**non-invasive**)
- Brain scans (e.g. MRI, PET or CT) (**non-invasive**)
- Spinal fluid biomarker protein analysis (**invasive**)

How good are doctors in predicting Alzheimer's based on MRI images? (Lombardi et al. 2020)

Correct classifications = 72%

Fraction of missed demented cases = 27%

Our aim

Develop a robust model that can predict Alzheimer's based on MRI images.

Who would use our model?

Neurologists

What the model could help with:

- Provide a second opinion about the diagnosis
- Save money and time for further tests

Datasets

OASIS *(oasis-brains.org)*
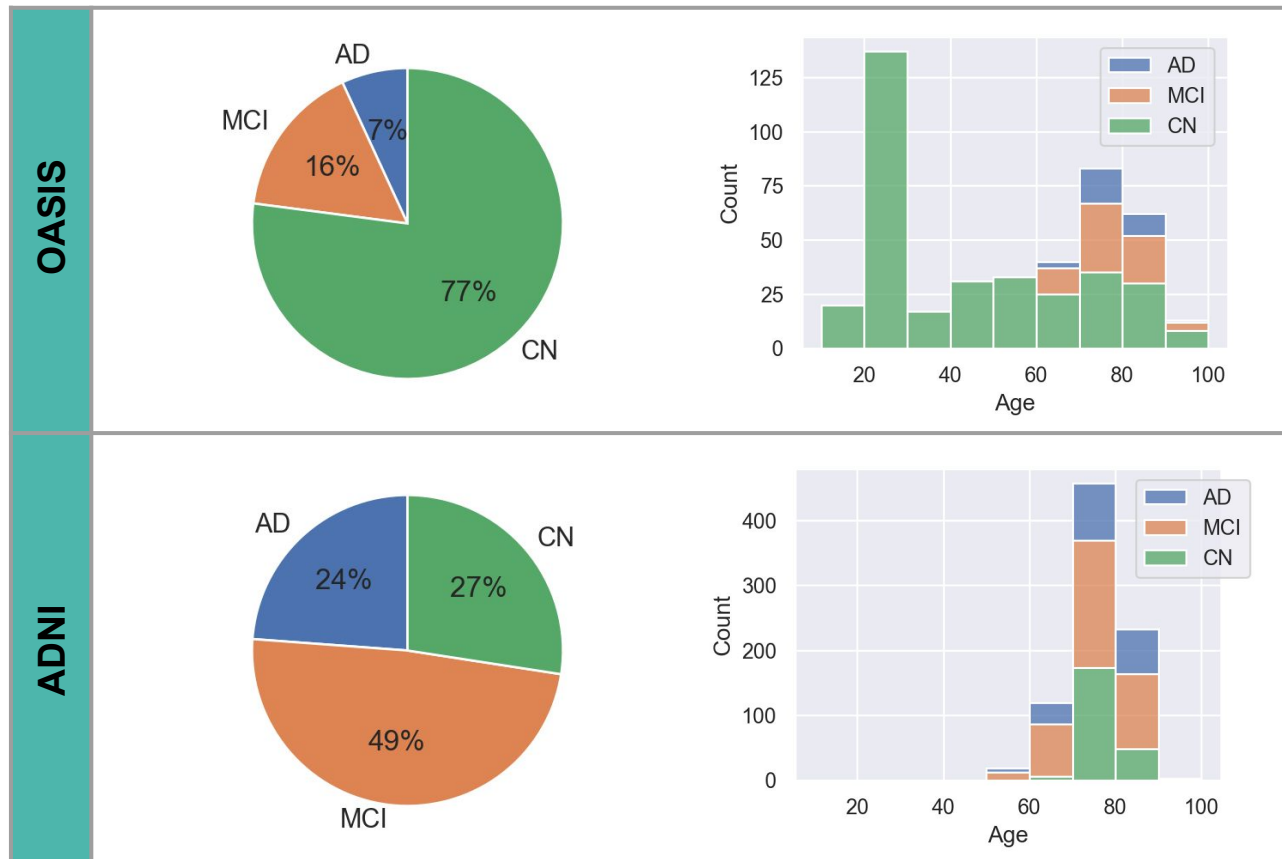- 2D and 3D MRI images of 416 subjects
- Demographic and social data

ADNI *(adni.loni.usc.edu)*
- 3D MRI images of 826 subjects
- Demographic and medical test results
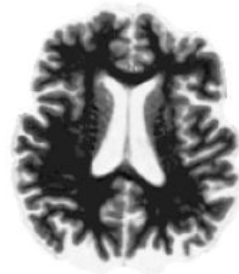
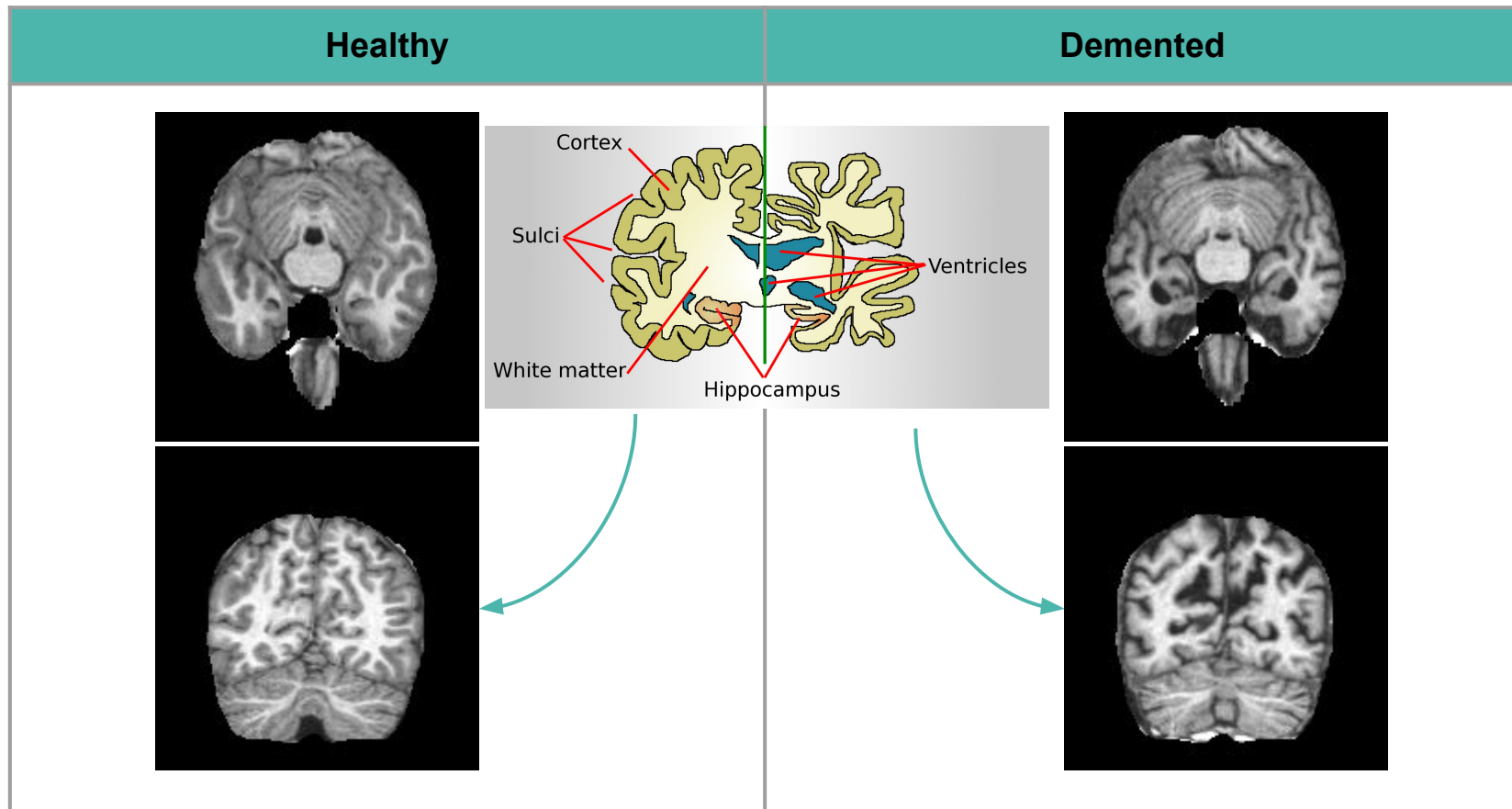|	demographic				medical assessm.			cognitive tests				brain meas.		
	Sex	Age	Educ	Social	APOE	ABETA	…	MMSE	ADAS11	CDR	…	Ventr	Hippoc	…
OASIS	✓	✓	✓	✓	✗	✗	…	✓	✗	✓	…	✗	✗	…
ADNI	✓	✓	✓	✗	✓	✓	…	✓	✓	✓	…	✓	✓	…

Overview of the data: demographic

CN = cognitively normal
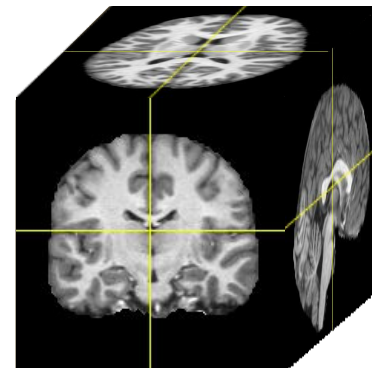
MCI = mild cognitive impairment

AD = Alzheimer's disease

7

Overview of the data: demographic

OASIS

ADNI

Combined dataset
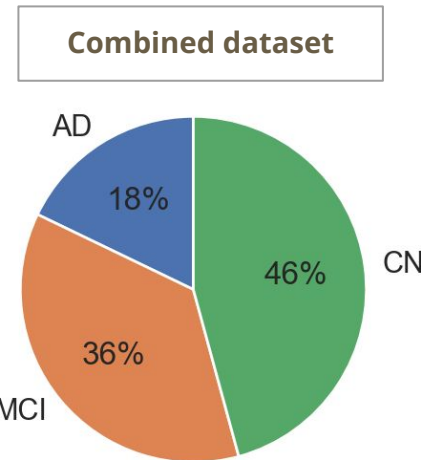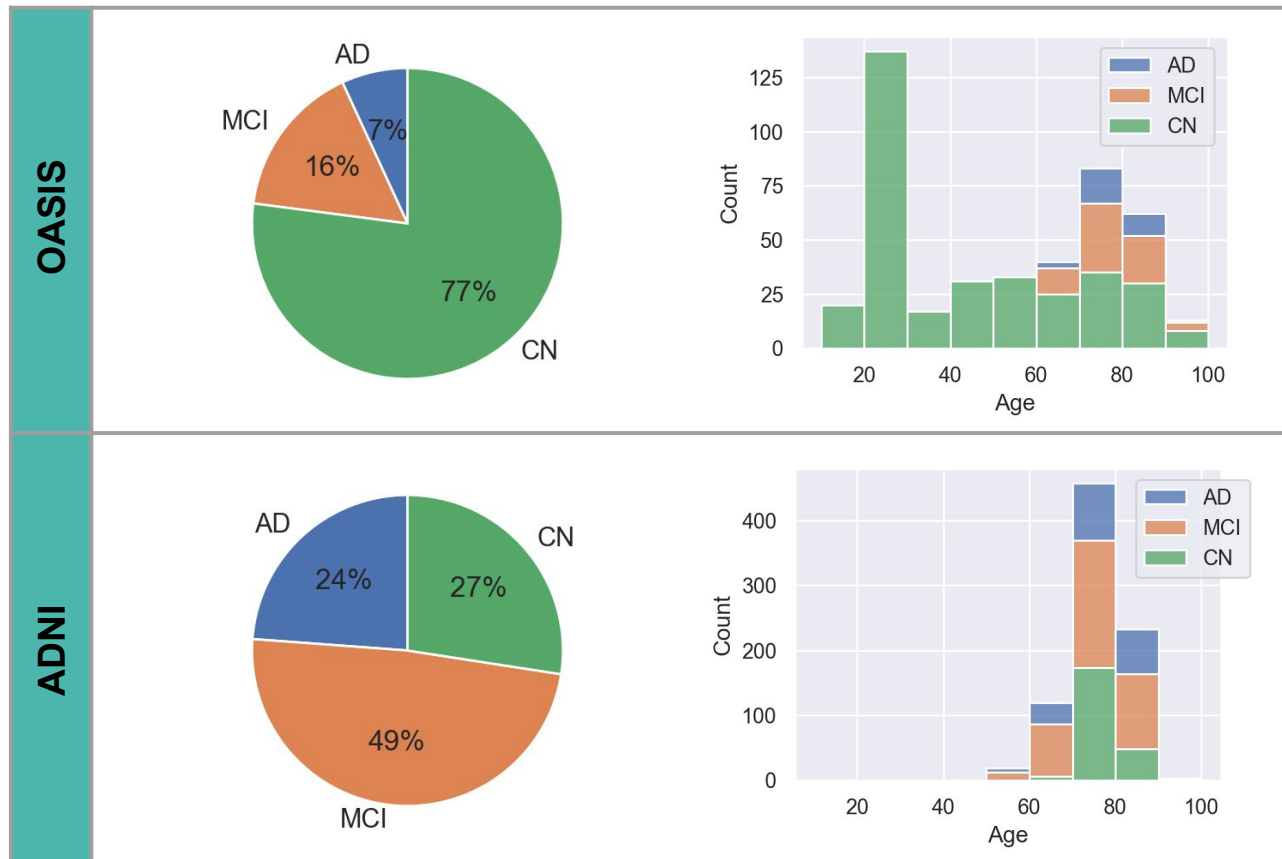
CN = cognitively normal

MCI = mild cognitive impairment

AD = Alzheimer's disease

Images

Healthy	Demented

Cortex

Sulci

Ventricles

White matter

Hippocampus

Our Approach: Preprocessing

OASIS:

- already scaled to Atlas "standard brain" coordinates

ADNI:

- centered to same locations as OASIS

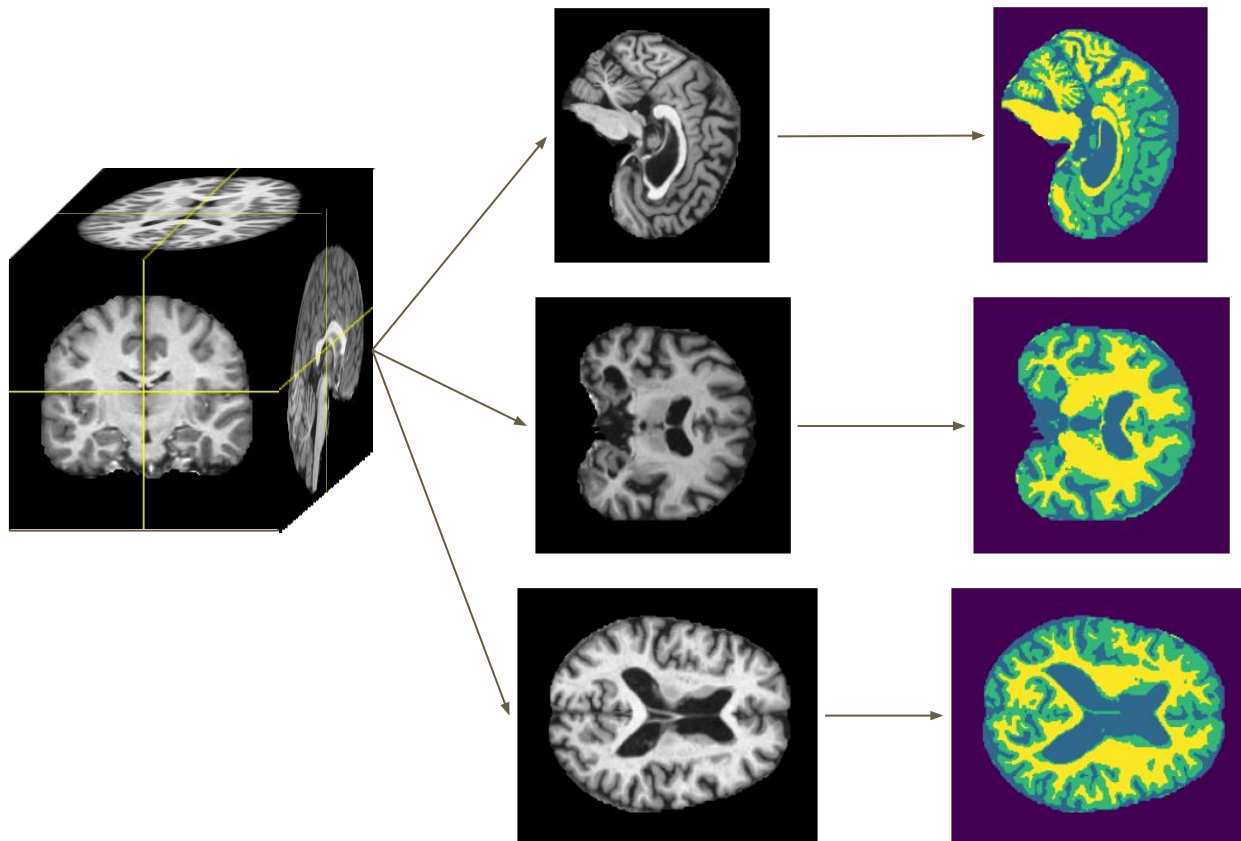- cropped to same dimensions
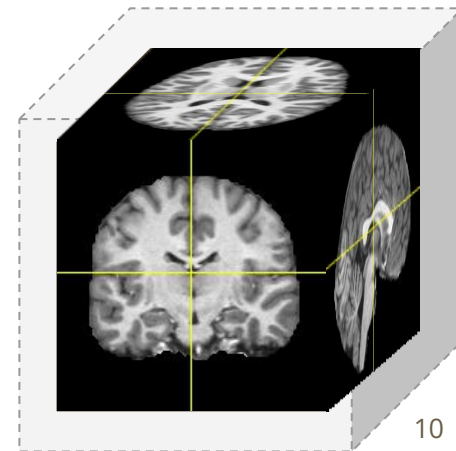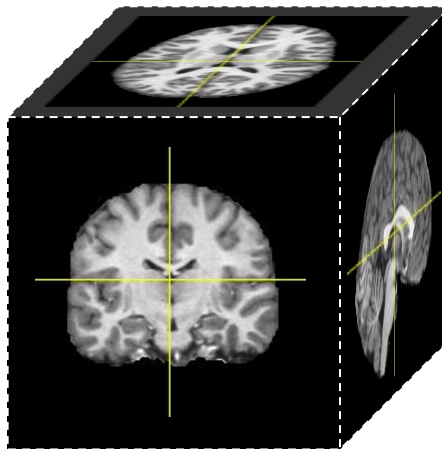
Preprocessing: Input selection
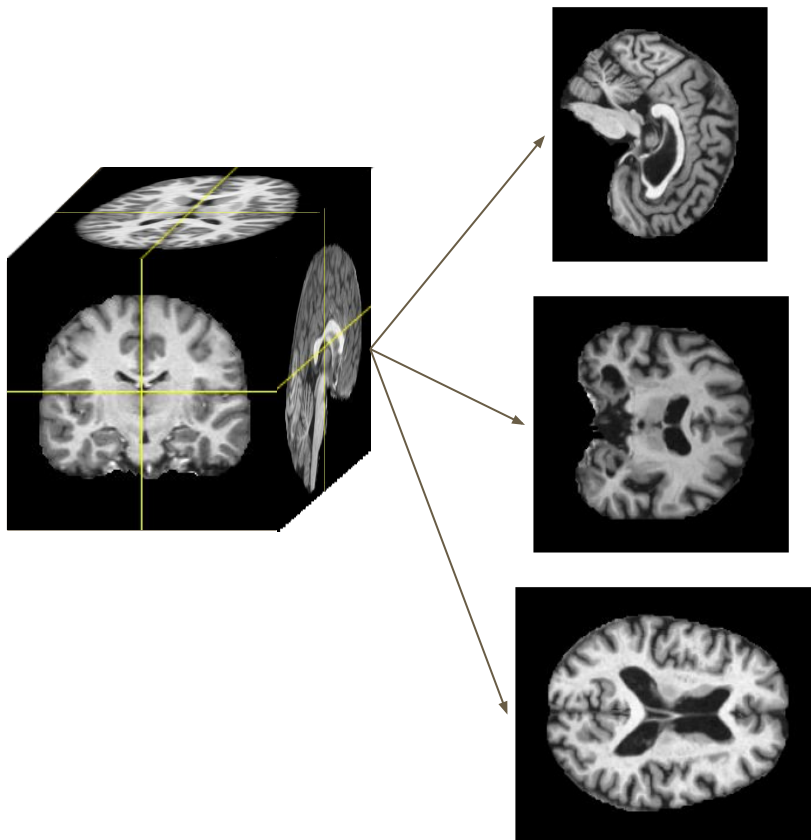
Find the best slice for each view that gives the most information

Our approach:

We searched for a specific slice number that gives the best result and used this slice for all images

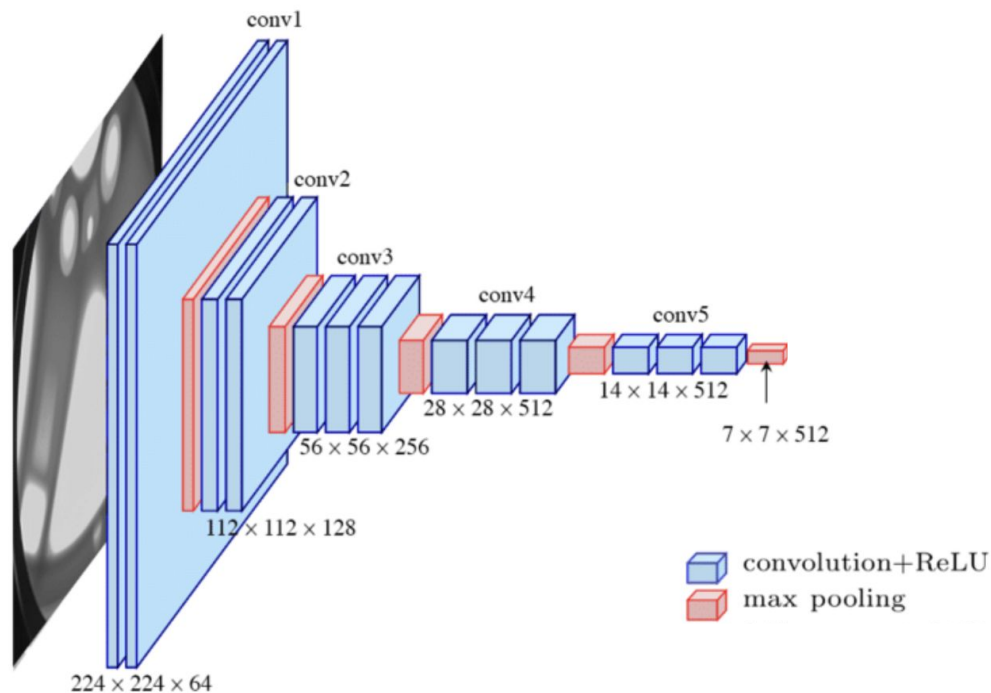(i.e. best slice is #90)

Preprocessing: Segmentation

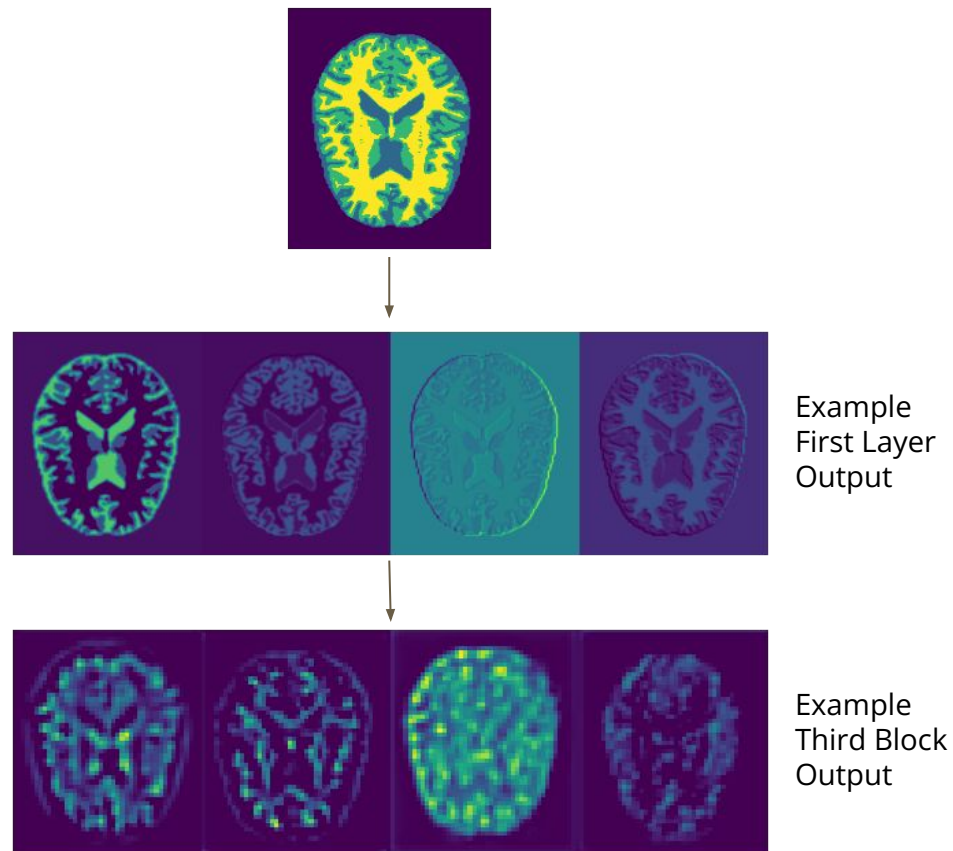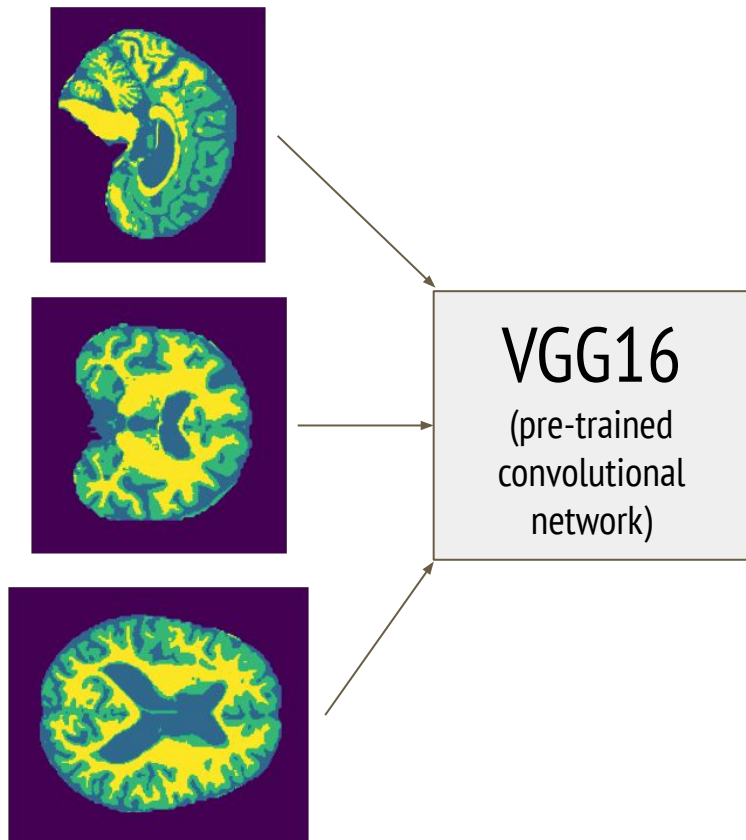**Segmentation of the brain tissues**

White Matter (WM): yellow
Gray Matter (GM): green
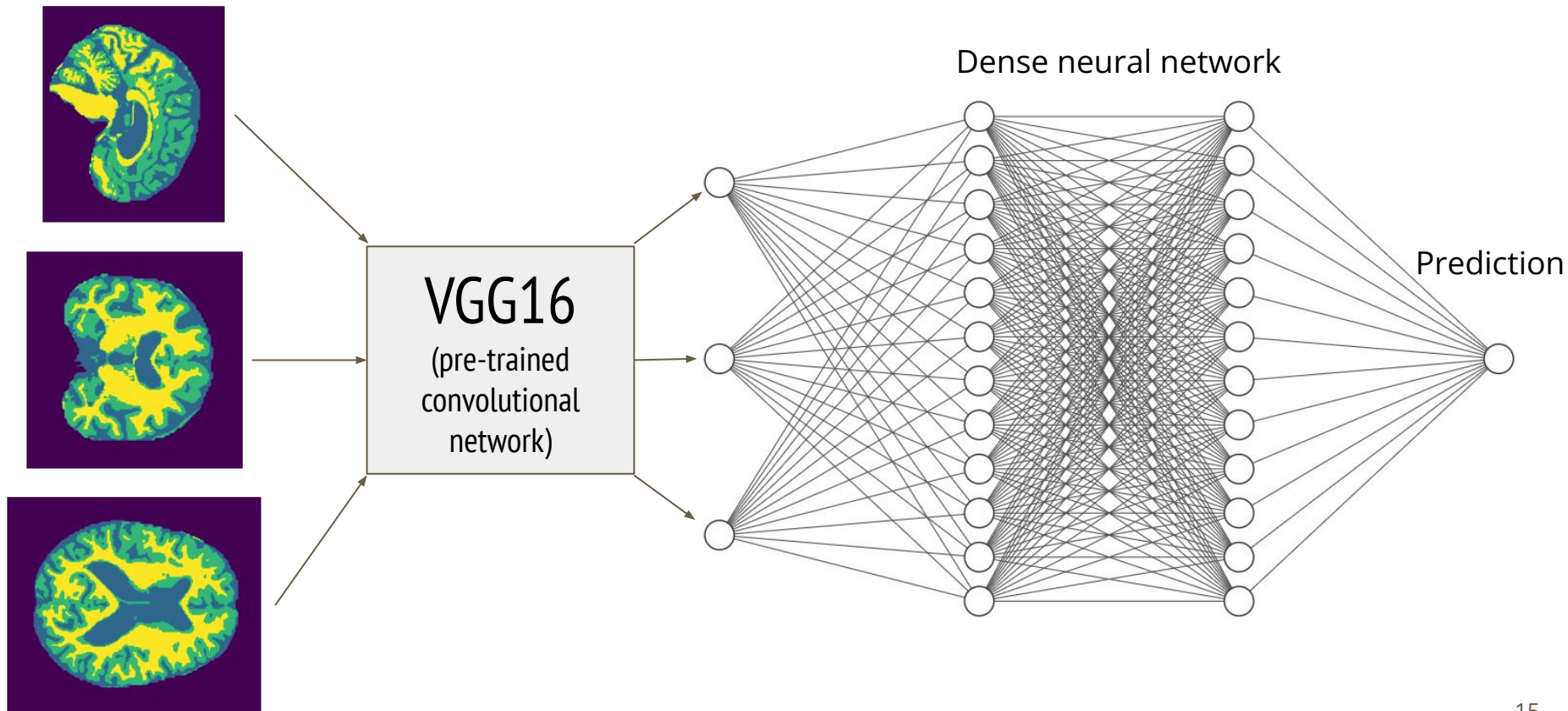Cerebrospinal Fluid (CSF): blue

The modeling process

VGG16 is a convolutional neural network that is trained on more than a million images from the ImageNet database
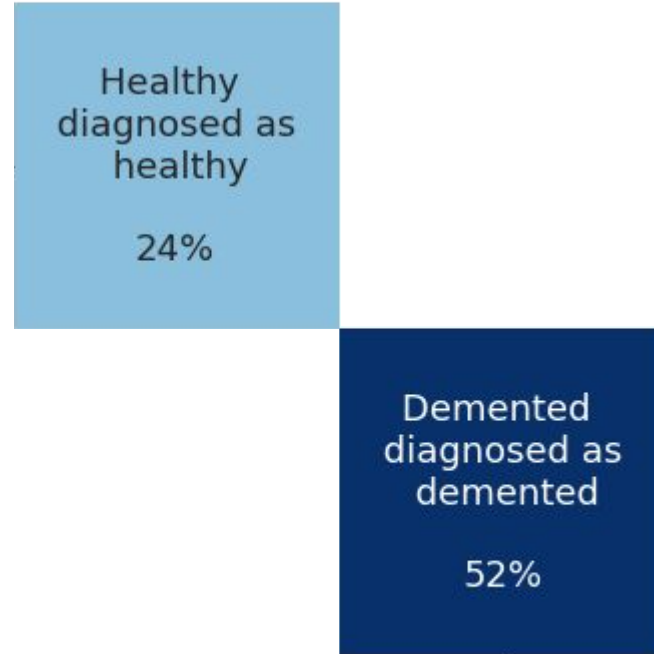

conv1

conv2

conv3

conv4

conv5

$224 \times 224 \times 64$

$112 \times 112 \times 128$

$56 \times 56 \times 256$

$28 \times 28 \times 512$

$14 \times 14 \times 512$

$7 \times 7 \times 512$

convolution+ReLU

max pooling

The modeling process

VGG16
(pre-trained convolutional network)

Example First Layer Output

Example Third Block Output

The modeling process

Modelling Results

Final model:

- Correct classification in 76% of cases

Healthy
diagnosed as
healthy

24%

Demented
diagnosed as
demented

52%

Modelling Results

Final model:

- Correct classification in 76% of cases
- Fraction of missed demented cases = 6%

Healthy diagnosed as healthy — 24%

Demented diagnosed as healthy — 3%

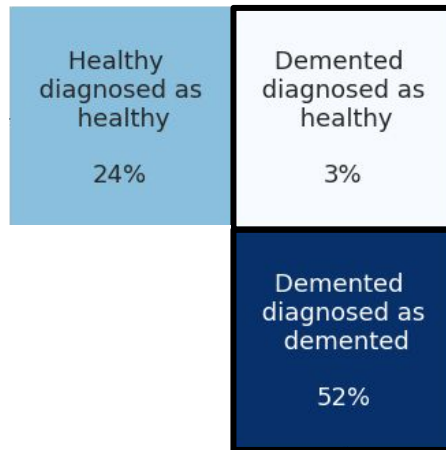Demented diagnosed as demented — 52%
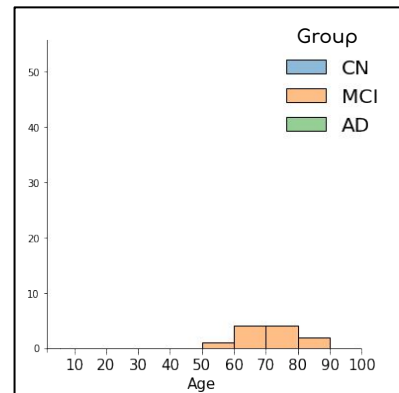
Modelling Results

Final model:

- Correct classification in 76% of cases
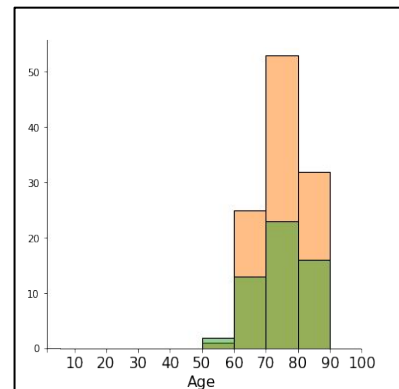- Fraction of missed
  demented cases = 6%

Error analysis:

- undetected instances are all mild cases
  => MCI is very hard to detect

Healthy diagnosed as healthy	Demented diagnosed as healthy
24%	3%
	Demented diagnosed as demented
	52%
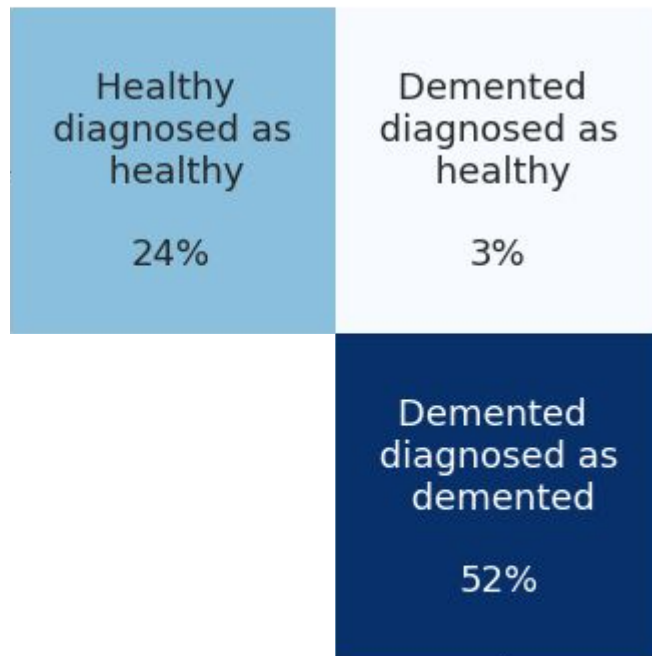
Missed Alzheimer cases

Detected Alzheimer cases

Modelling Results

Final model:

- Correct classification in 76% of cases
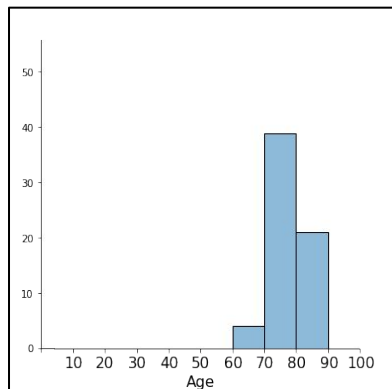- Fraction of missed
  demented cases = 6%

Healthy diagnosed as healthy 24%	Demented diagnosed as healthy 3%
Healthy diagnosed as demented 21%	Demented diagnosed as demented 52%

Error analysis:

- undetected instances are all mild cases
  => MCI is very hard to detect
- age related degeneration
  => older healthy brains misclassified

Misclassified healthy cases
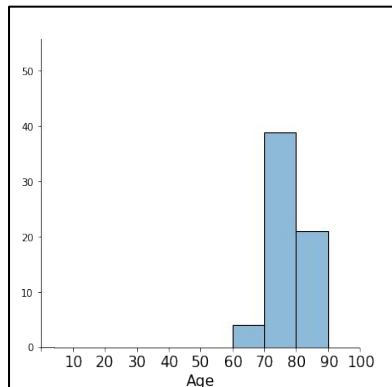
Modelling Results

Final model:

- Correct classification in 76% of cases
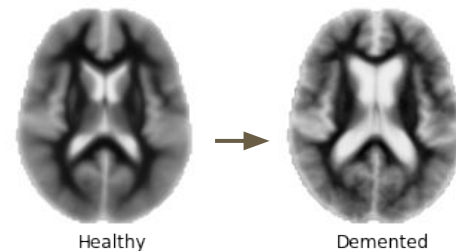- Fraction of missed
  demented cases = 6%

Error analysis:

- undetected instances are all mild cases
  => MCI is very hard to detect
- age related degeneration
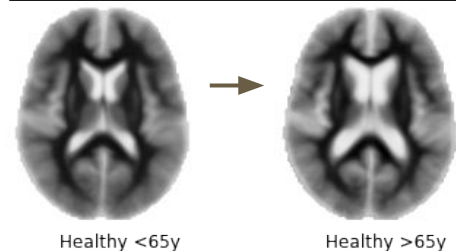 => older healthy brains misclassified

Healthy diagnosed as healthy	Demented diagnosed as healthy
24%	3%
Healthy diagnosed as demented	Demented diagnosed as demented
21%	52%

Misclassified healthy cases

Alzheimer's degeneration

Healthy → Demented

Age related degeneration

Healthy <65y → Healthy >65y

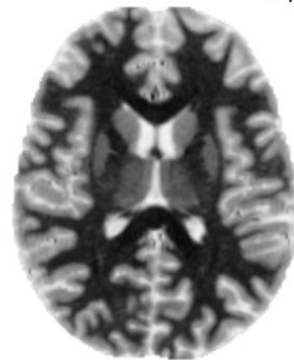*#1 reason for*
misdiagnosis
by professionals

Summary
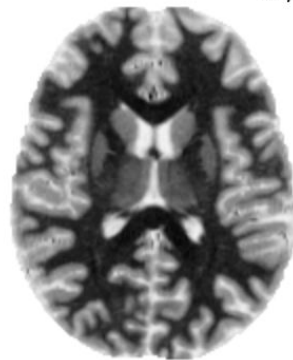
- robust model trained on high-variance data

- works well with only three 2D slices

- 4% increase in accuracy

- Fraction of missed MCI/AD cases decreased by 21%
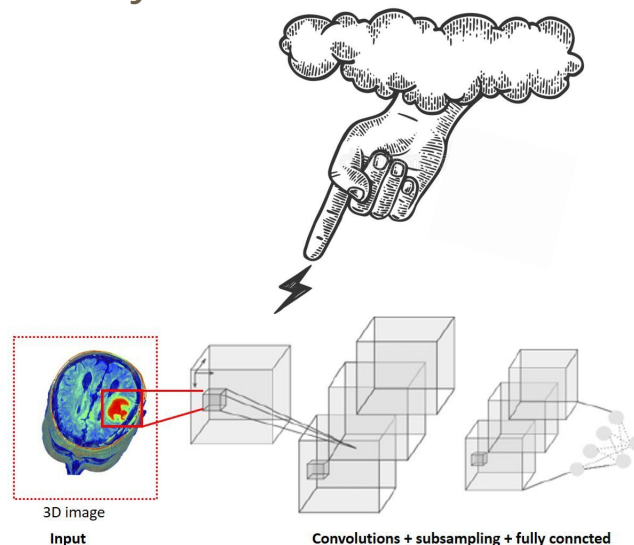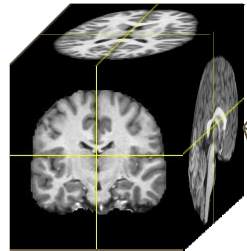
Summary

- robust model trained on high-variance data
- works well with only three 2D slices
- 4% increase in accuracy
- Fraction of missed MCI/AD cases decreased by 21%
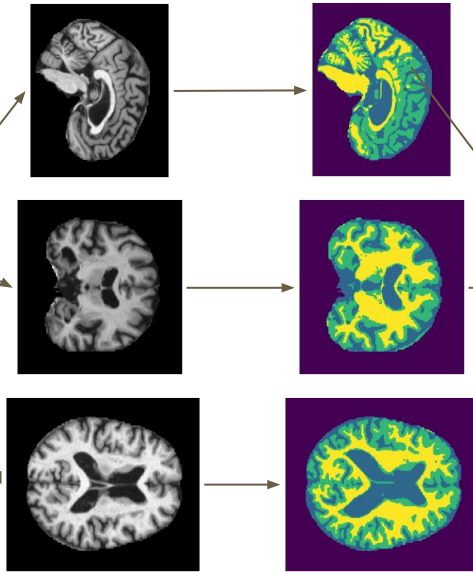
Outlook

- Harness the power of the cloud

  => develop 3D convolutional network
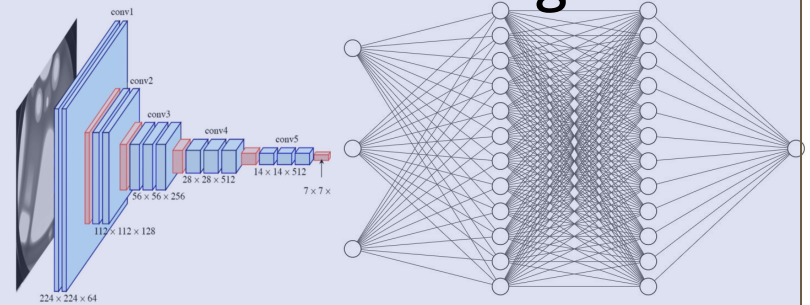
  => automated Atlas correction
     and denoising

3D image
Input

Convolutions + subsampling + fully connected

3D MRI Images

Get slices and image segmentation

BrainWatchers Magic Box

conv1
conv2
conv3
conv4
conv5

$224 \times 224 \times 64$
$112 \times 112 \times 128$
$56 \times 56 \times 256$
$28 \times 28 \times 512$
$14 \times 14 \times 512$
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