

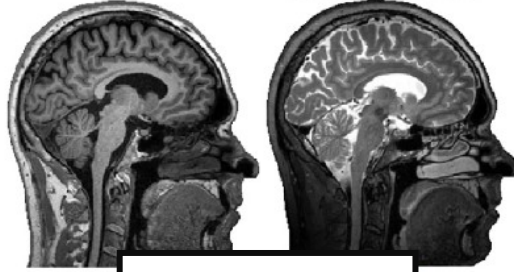
Medical Image Analysis

NBE-E4010

AI in medical imaging



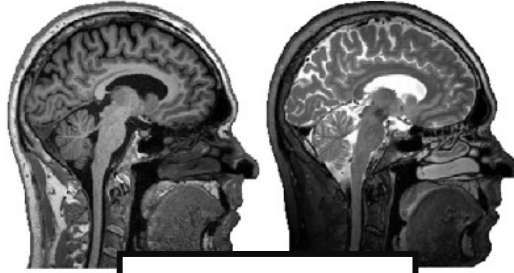
scanner



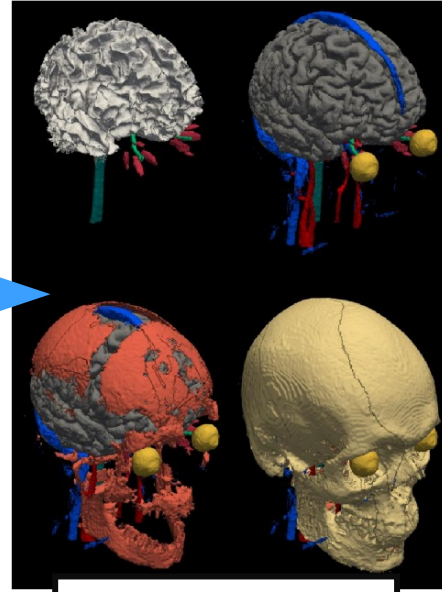
images

- acquire images faster
- visualize more details

AI in medical imaging



images



information

- expose the “unseeable”
- measure more consistently
- analyze images faster

Exposing the “unseeable”

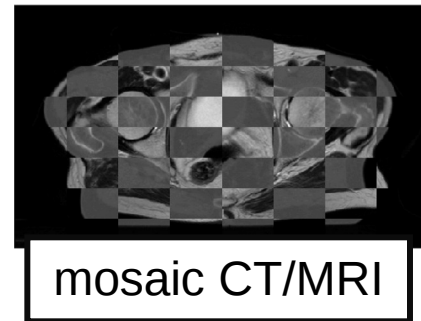
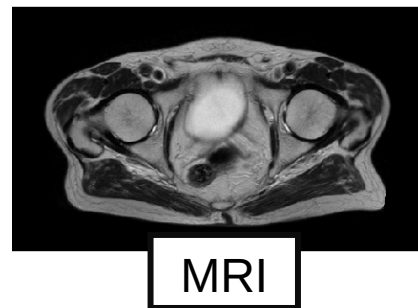
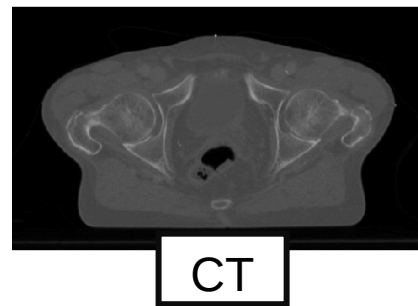
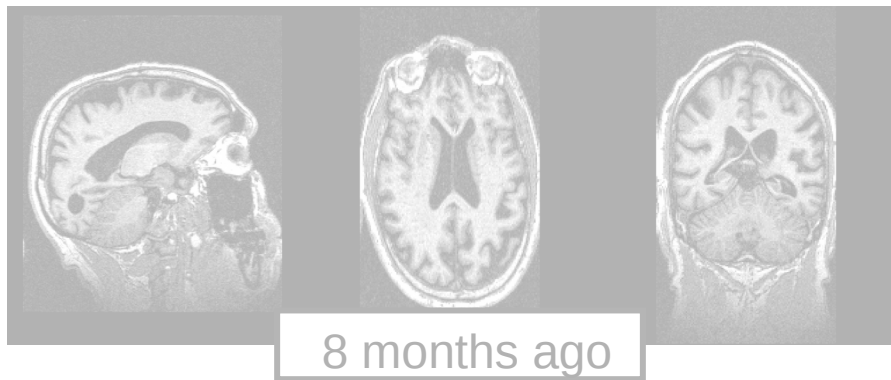
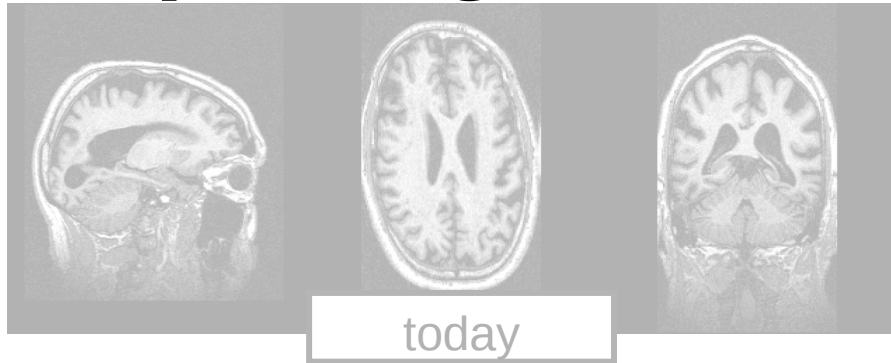


today

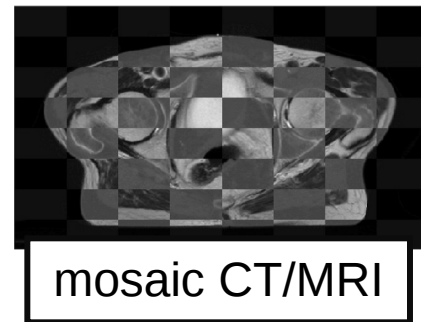
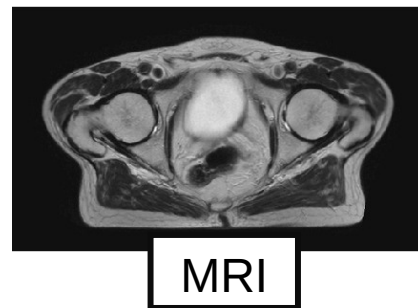
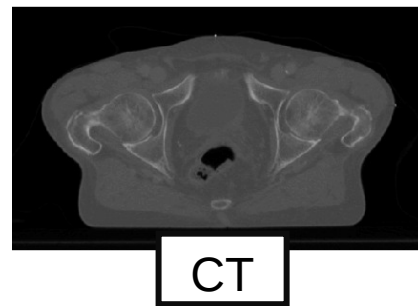
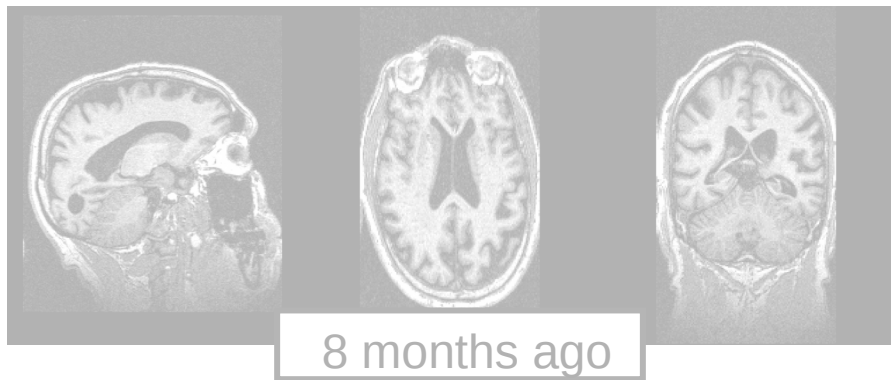
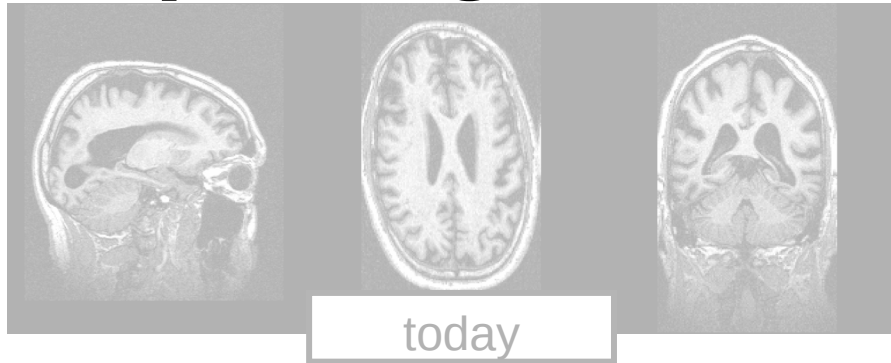


8 months ago

Exposing the “unseeable”



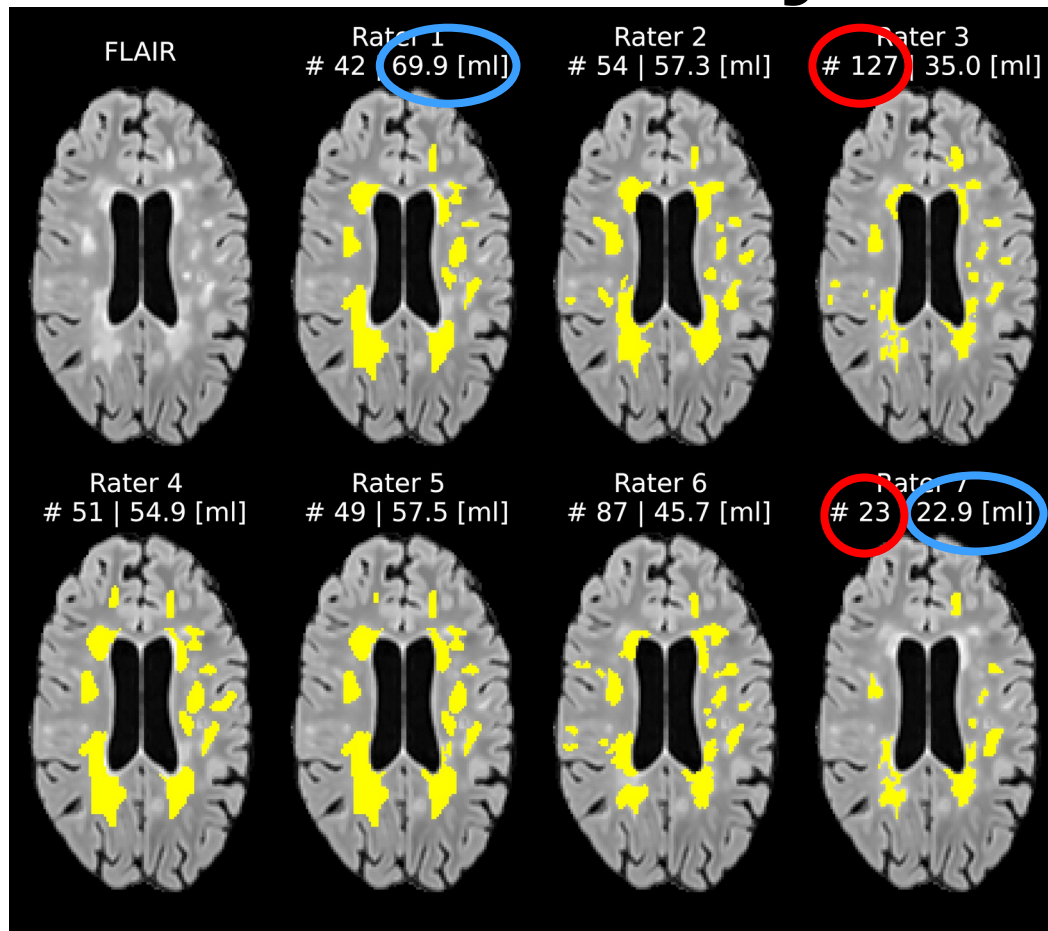
Exposing the “unseeable”



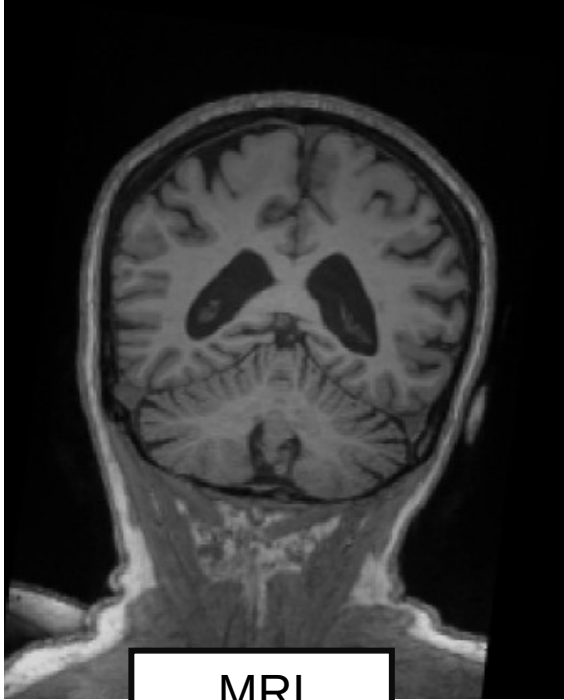
Measuring more consistently

Quantifying lesions in multiple sclerosis (MS):

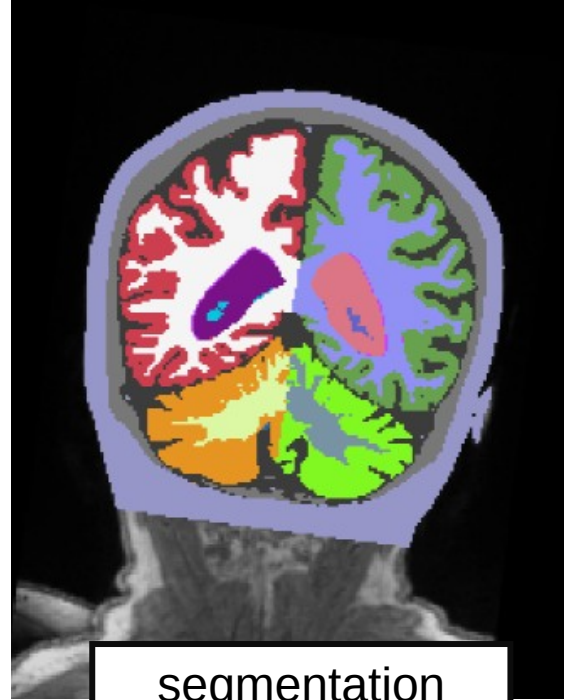
- number (#)
- volume (ml)



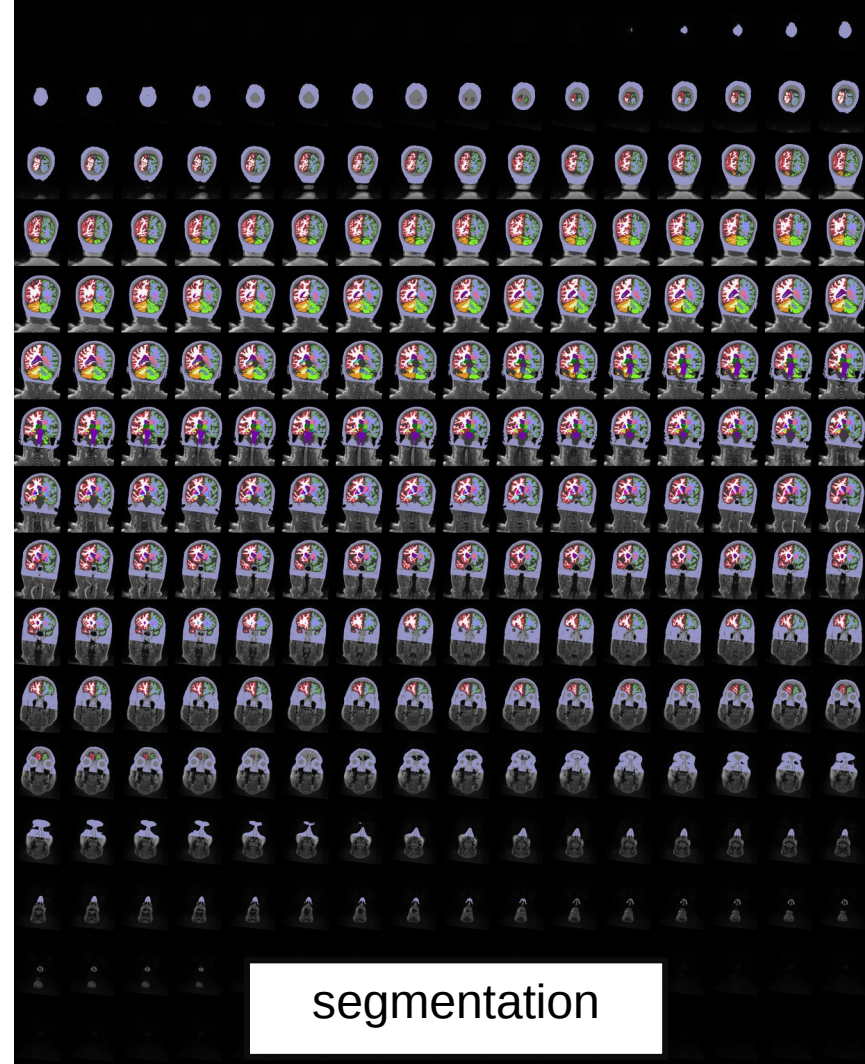
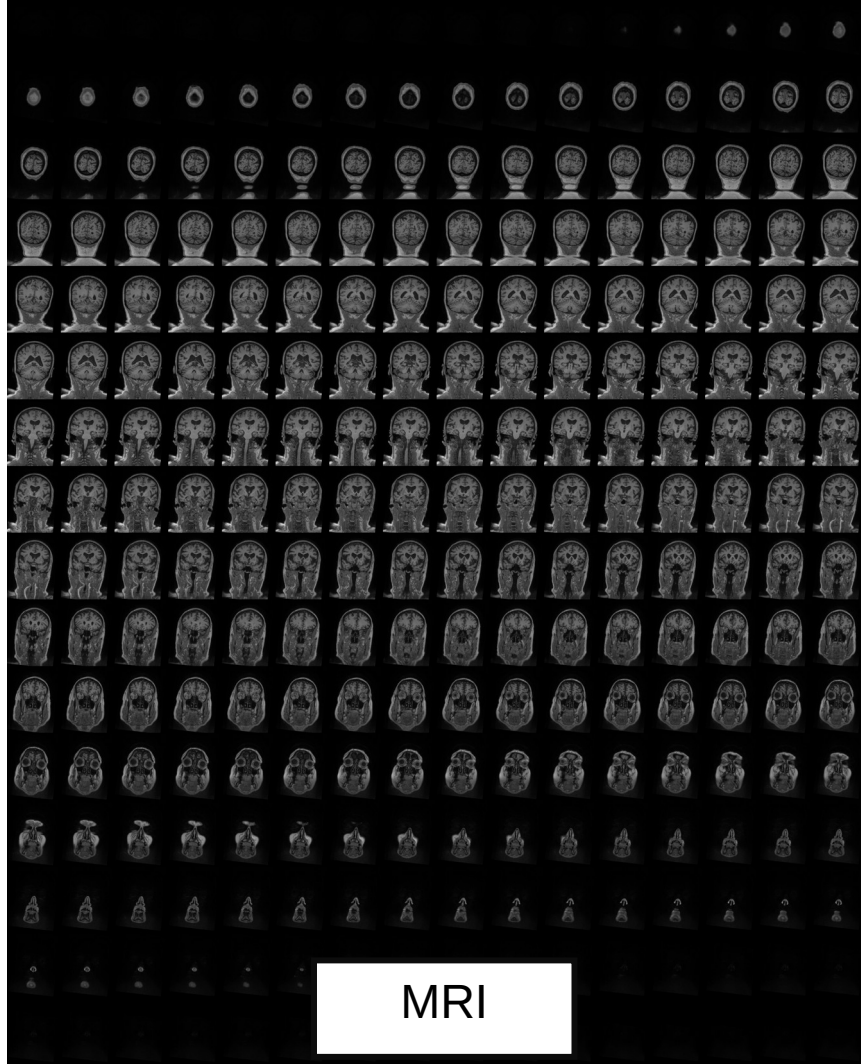
Analyzing images faster



MRI

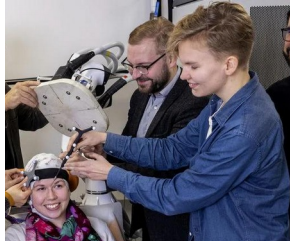


segmentation



Who are we?

- ✓ Koen Van Leemput (Professor, Neuroscience and Biomedical Engineering, Aalto University)
- ✓ Ida Granö (Doctoral Researcher, Neuroscience and Biomedical Engineering, Aalto University)
- ✓ Raymond Khazoum (Doctoral Researcher, Computer Science, Aalto University)



- ✓ Axel Thielscher (Professor, Health Technology, Technical University of Denmark)
- ✓ Oula Puonti (Postdoctoral Researcher, Health Technology, Technical University of Denmark)
- ✓ Merle Diedrichsen (Doctoral Researcher, Health Technology, Technical University of Denmark)



Who are **you**?

- ✓ MSc in Life Science Technologies: 46
- ✓ Exchange studies: 8
- ✓ BSc in Electrical Engineering: 4
- ✓ MSc in Computer, Communication and Information Sciences: 3
- ✓ PhD in Science: 2
- ✓ BSc in Chemical Technology: 2
- ✓ MSc in Engineering Physics: 1
- ✓ BSc in Engineering: 1

67 students at Aalto

37 students at the
Technical University
of Denmark

Learning objectives

After this course you should be able to:

- ✓ **Implement** smoothing and interpolation operations in images
- ✓ **Explain** coordinate systems used in medical imaging
- ✓ **Perform** landmark-based and intensity-based image registration
- ✓ **Select** the most appropriate similarity measure for specific image registration problems
- ✓ **Implement** rigid, affine and nonlinear spatial transformation models
- ✓ **Solve** segmentation problems using generative models
- ✓ **Perform** image segmentation using example-based learning
- ✓ **Weigh** the advantages and limitations of model- vs. example-based techniques



Teaching form

Lectures:

- ✓ Tuesdays 14:15-16:00
- ✓ Live-streamed to/from Denmark
- ✓ Konetekniikka 1, 216 (until mid-October); Terveysteknologian talo, F239a (from mid-October)
- ✓ Two guest lectures: Jyrki Lötjönen (Combinostics) and Eero Salli (HUS Radiology)

Exercises:

- ✓ Mondays 12:15-14:00
- ✓ Terveysteknologian talo, luentosali 1 - F175a
- ✓ Python + Jupyter notebooks
- ✓ Group-work (max. 3 students per group)
- ✓ 2-3 weeks to submit a group report (6 reports in total)
- ✓ **Grading:** Peergrade + teachers' final assessment

no exam!

Logistics

<https://mycourses.aalto.fi/>

- ✓ Course material (lecture slides, book, ...)
- ✓ Announcements
- ✓ Discussion fora
- ✓ Submission of exercise reports

▼ Week 1

Lecture: Introduction to the course, Python and Jupyter notebooks

▼ Week 2

Lecture: Image smoothing and interpolation

▼ Week 3

Exercise session: Image smoothing and interpolation

Discussion forum: Image smoothing and interpolation exercise

Lecture: Coordinate systems, spatial transformations, landmark-based registration

▼ Week 4

Exercise session: Image smoothing and interpolation (cont.)

Lecture: Intensity-based methods for registration

▼ Week 5

Exercise session: Landmark-based registration

Discussion forum: Landmark-based registration exercise

Lecture: Nonlinear registration with Gauss-Newton

▼ Week 6

Exercise session: Mutual Information-based registration

Discussion forum: Mutual information-based registration

Lecture: Model-based segmentation I

▼ Week 7

Exercise session: Nonlinear registration

Discussion forum: Nonlinear registration exercise

Lecture: Model-based segmentation II

▼ Week 8

Exercise session: Model-based segmentation

Discussion forum: Model-based segmentation

Neural Networks

▼ Week 9

Exercise session: Model-based segmentation (cont.)

Guest lecture: Jyrki Lötjönen (Combinotics)

▼ Week 10

Exercise session: Neural networks

Discussion forum: Neural networks exercise

Guest lecture: Eero Salli (HUS)

▼ Week 11

Exercise session: Neural networks (cont.)

Lecture: Neural networks in practice I

▼ Week 12

Lecture: Neural networks in practice II

Python and Jupyter Notebooks

- ✓ Python: <https://lectures.scientific-python.org/>
- ✓ Jupyter Notebooks:
<https://www.dataquest.io/blog/jupyter-notebook-tutorial/>

Jupyter exampleNotebook (autosaved)

File Edit View Insert Cell Kernel Widgets Help Not Trusted Python 3 (ipykernel)

Image Smoothing and Interpolation

Linear regression

Let $\mathbf{x} = (x_1, \dots, x_D)^T$ denote the spatial position in a D -dimensional space. In medical imaging, D is typically 2 or 3. Given N measurements $\{t_n\}_{n=1}^N$ at locations $\{\mathbf{x}_n\}_{n=1}^N$, a frequent task is to predict the value t at a new location \mathbf{x} . A simple model, known as `lemph` (linear regression), uses the function value

$$y(\mathbf{x}; \mathbf{w}) = w_0 + w_1 x_1 + \dots + w_D x_D$$

as its prediction, where w_0, \dots, w_D are tunable weights that need to be estimated from the available measurements. A more general form uses nonlinear functions of the input locations instead:

$$y(\mathbf{x}; \mathbf{w}) = w_0 + \sum_{m=1}^{M-1} w_m \phi_m(\mathbf{x}),$$

which greatly increases the flexibility of the model. Here the functions $\phi_m(\mathbf{x})$ are known as `lemph` (basis functions), and it is often convenient to define an additional "dummy" basis function $\phi_0(\mathbf{x}) = 1$, so that the model can be written as

$$y(\mathbf{x}; \mathbf{w}) = \sum_{m=0}^{M-1} w_m \phi_m(\mathbf{x}),$$

where $\mathbf{w} = (w_0, \dots, w_{M-1})^T$ are M tunable parameters.

In order to find suitable values of the parameters of the model, the following energy can be minimized with respect to \mathbf{w} :

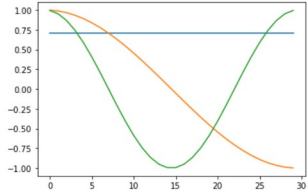
$$E(\mathbf{w}) = \sum_{n=1}^N \left(t_n - \sum_{m=0}^{M-1} w_m \phi_m(\mathbf{x}_n) \right)^2,$$

which simply sums of the squared distances between the measurements t_n and the model's predictions $y(\mathbf{x}_n; \mathbf{w})$.

```
In [4]: #
import numpy as np
from matplotlib import pyplot as plt
plt.ion()

#
N = 30;
ns = np.arange(N).reshape(-1, 1)
A = np.cos( np.pi * ( ns + 0.5 ) * np.arange(3) / N )
A[:, 0] *= 1/np.sqrt(2) # DC component is scaled differently
plt.figure()
plt.plot( ns, A )


Out[4]: [<matplotlib.lines.Line2D at 0x7fdf2fc61a60>,
<matplotlib.lines.Line2D at 0x7fdf2fc61a98>,
<matplotlib.lines.Line2D at 0x7fdf2fc6fc70>]
```



Jupyter notebooks at Aalto

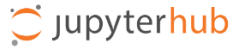
<https://jupyter.cs.aalto.fi/>

Server Options

- ☐ Python: General use (JupyterLab) v6.1.4
-  ☒ Python: General use (classic notebook) v6.1.4
- ☐ R: General use (JupyterLab) v5.0.25-jh401
- ☐ Julia: General use (JupyterLab) v5.0.16-jh401
- ☐ (testing) Python: General use (JupyterLab) v6.0.0
- ☐ Old version (JupyterLab) v5.0.25

Jupyter notebooks at Aalto

<https://jupyter.cs.aalto.fi/>



Logout Control Panel

Files Running Clusters Assignments Nbextensions

Select items to perform actions on them.

Upload New ↕

<input type="checkbox"/> 0 ▾	📁 / notebooks	Name ▾	Last Modified	File size
	📁 ..		seconds ago	
<input type="checkbox"/>	📄 eventTest.ipynb		a day ago	44.8 kB
<input type="checkbox"/>	📄 interactiveViewerBackend.ipynb		12 hours ago	660 kB
<input type="checkbox"/>	📄 testje.ipynb		a day ago	2.44 MB
<input type="checkbox"/>	📄 Untitled.ipynb		3 months ago	3.83 kB
<input type="checkbox"/>	📄 Untitled1.ipynb		a day ago	2.1 kB
<input type="checkbox"/>	📄 Untitled2.ipynb		a day ago	2.93 kB
<input type="checkbox"/>	📄 Untitled3.ipynb		12 hours ago	438 kB
<input type="checkbox"/>	📄 IXI002-Guys-0828-T1.nii.gz		a day ago	6.94 MB

Jupyter notebooks at Aalto



<https://jupyter.cs.aalto.fi/>

Logout

Control Panel

Files

Running

Clusters

Assignments

Nbextensions

Select items to perform actions on them.

Upload

New ▾



☐ 0 ▾

/ notebooks

Name ▾

Notebook:

Bash

Python 3

Other:

Text File

Folder

Terminal



..

☐ eventTest.ipynb

☐ interactiveViewerBackend.ipynb

☐ testje.ipynb

☐ Untitled.ipynb

☐ Untitled1.ipynb

☐ Untitled2.ipynb

☐ Untitled3.ipynb

☐ IXI002-Guys-0828-T1.nii.gz

a day ago

2.1 kB

a day ago

2.93 kB

12 hours ago

438 kB

a day ago

6.94 MB



Aalto-yliopisto
Aalto-universitetet
Aalto University

Copyrights

"Accurate and robust whole-head segmentation from magnetic resonance images for individualized head modeling" by Puonti et al. NeuroImage (2020), licensed under CC-BY-NC-ND