AI in Medicine I
WiSe 2023/24

Technical University Munich
Department of Informatics

I31 - AI in Medicine and Healthcare
I32 - Computational Imaging in AI and Medicine

Practical exercise 2 **9. Nov. 2023**

Brain tissue segmentation

Submission deadline: 24. Nov. 2023, 11:59 p.m.

Please submit your solutions via Moodle.
The corresponding tutorial session is

9. Nov. 2023, 4:15-5:45 p.m. in lecture hall 5901.EG.051

For questions regarding this exercise sheet, please contact: `alina.dima@tum.de`, `yundi.zhang@tum.de`
For general questions, please contact: `course.aim-lab@med.tum.de`

Segmentation of different tissues from MRI scans of the brain is an important step for further downstream applications such as disease prediction, classification or brain age estimation. The goal of the coursework is to implement classical and deep learning approaches for segmentation of different tissue types in MRI scans of the brain, i.e., background, cerebrospinal fluid (CSF), white matter (WM), and gray matter (GM). We provide data from a total of 652 healthy subjects (552 train / 65 validation / 65 test). Each approach will require a processing pipeline with different components that you will need to implement using methods that were discussed in the lectures and tutorials. There are dedicated parts in the Jupyter notebook that contain some detailed instructions and helper code. The deliverables for the submission are an archive containing the code provided completed as well as a report explaining your strategies and choices for each coding task in this practical (Tasks 1-3) and your answers to Task 4.

1. (15% points) **Evaluation and Visualization**. Your first task is to implement methods to quantitatively and qualitatively evaluate the performance of the segmentation algorithms.
   (a) (5% points) **Evaluation metrics**. Implement the Dice similarity coefficient, precision and recall to evaluate the performance of segmentation algorithms. Beware of the individual classes!
   What is the relationship between the Dice coefficient, precision and recall? What are their pros and cons? Provide your answer in the report.
   (b) (5% points) **Visual inspection of best/worst predictions**. Given a set of predictions, visualize the images with the best and worst Dice scores across the entire test set. Complete the corresponding code block in the Jupyter notebook.
   (c) (5% points) **Results summary**. Given a set of predictions for a number of models, create a summary figure of your choice (e.g. table, bar plot) which visualizes all of the metric values. Visualize multiple metrics (Dice coefficient, precision, and recall), each computed for every tissue type. A sample metric dictionary is provided in the *Jupyter* notebook.
   (d) (Bonus points) **Other metrics**. What other evaluation metrics are there for image segmentation? How do they differ from the ones implemented in Task 1a?

2. (30% points) **Unsupervised Segmentation**. The first segmentation approach that you are going to implement is based on the intensity distribution of the different brain tissues. Implement two different unsupervised learning methods to leverage the different intensity profiles of the tissues.
   (a) (15% points) **Unsupervised method 1**. Implement an unsupervised learning-based segmentation method of your choice.
   (**Hint**: *sklearn* has implementations of unsupervised methods)
   (b) (15% points) **Unsupervised method 2**. Implement a second unsupervised learning-based segmentation method of your choice.

3. (20% points) **Deep Supervised Segmentation**. The second approach is to use deep supervised training to segment the different tissue types. Implement, train and evaluate a U-Net to segment the 4 tissues (CSF, WM, GM, and background). Feel free to choose the number of layers, the number of features within convolutional layers, the number of convolutions within each layer, and concatenation strategy.. Train the networks from scratch (no pre-training). Used the provided train/val/split.

   Hint: You can use pre-defined models, e.g., from *torchvision*.

4. (35% points) **Analysis**. After you have implemented a few segmentation methods, it's time to analyze the results. Answer all of the following questions in the report.
   (a) (5% points) What is the most intuitive approach to segment the images based on the density plot of the input (Hint: take a look a the density plot in the first block of Task 2 in the *Jupyter* notebook)?
   (b) (5% points) How did method 2a perform? Comment based on the quantitative and qualitative results.
   (c) (5% points) How did method 2b perform? Comment based on the quantitative and qualitative results.
   (d) (5% points) Which unsupervised method performed better? Why?
   (e) (5% points) How did method 3 perform? Comment based on the quantitative and qualitative results.
   (f) (5% points) Which approach (classical or DL) performed better? Why?
   (g) (5% points) What additional information in the volumes is used by the DL models compared to the unsupervised approaches in Task 2? Why is it helpful?