Medical Image Segmentation and Applications
Lab 3: Atlas segmentation

1 Introduction

In many medical image segmentation tasks, incorporating an anatomic or probabilistic atlas can be crucial for achieving spatially-consistent and accurate results. These atlases provide a standardized reference that can help to guide the segmentation process, ensuring that anatomical structures are identified in their expected locations, even when individual patient images may vary due to differences in acquisition conditions or anatomical variability. By offering a probabilistic representation of tissue distribution, an atlas can enhance the robustness of segmentation algorithms, particularly when dealing with complex tissue boundaries or low-contrast regions.

The objective of this second part of the assignment (corresponding to MISA) is to implement and compare various tissue segmentation strategies, utilizing both the tissue models and the probabilistic atlas constructed in the first part of the assignment. This involves utilizing these tools either independently or combined to segment new subjects, but also integrating them with the Expectation-Maximization (EM) algorithm, which was previously implemented in MISA.

Once the strategies are implemented, you should focus on evaluating their performance on the provided dataset, and explain your own experience about how the adjustments done to the EM algorithm affect the segmentation results.

In this lab you will learn to:

- Use probabilistic atlases in different segmentation approaches.
- Use your tissue models to segment new subjects.
- Integrate spatial information into EM.

2 Segmentation without EM

First of all, let's use the materials built in the first part of the assignment (probabilistic atlas and tissue models) to segment a new subject. Perform tissue segmentation using only the information provided by:

2.1. **Tissue models**: segmentation using just intensity information.

2.2. **Label propagation**: segmentation using just position information.

2.3. **Tissue models & label propagation**: segmentation using both intensity and position information.

3 EM initialization

Let's now use the probabilistic segmentation obtained by your atlas and tissue models to initialize the EM algorithm from the previous session:

3.1. **k-Means initialization** (algorithm from past session): segmentation using only the subject's intensity information.

3.2. **Tissue models initialization**: segmentation using the intensity information from the training set and the target.

3.3. **Label propagation initialization**: segmentation obtained using position information from the atlas and the subject's intensity information.

4 Combine EM with atlas

Use both your atlas and the the well-known MNI atlas (available on Moodle) in combination with your EM. Select the initialization strategy of your choice from Section 3 (you can also combine tissue models & label propagation to initialize your EM, as you did in Section 2). Integrate the atlas' position information:

4.1. **A posteriori**. After algorithm convergence.

4.2. **Into EM**. You can choose to be more or less strict using the atlas information, depending on the selected "update frequency".

5 Evaluation

Evaluate the implemented algorithms from Sections 2-4 on the provided test set (available on Moodle). Report some qualitative results and also perform a quantitative analysis using the Dice Similarity Coefficient (DSC) metric.

Explain what you see in those results and if they are as you expected. You can write a small discussion with your assignment experience, answering questions such as:

- Which strategy provides the best quantitative results?
- How do they look qualitatively?
- Which initialization strategy performs better?
- Does the inclusion of spatial information improve the EM segmentation?
- Which atlas provides better results?
- Are the three tissues equally affected?

Submission

A single report will be required for both MIRA and MISA parts at the completion of the assignment, including:

- Brief explanation of the implemented methods: atlas construction (registration strategy, reference subject, etc.), tissue models, and segmentation strategies.
- Quantitative and qualitative evaluation of the segmentation methods from Sections 2-4.
- Small discussion about the obtained results.

Remember to include:

- Registration results for both intensities and labels.
- Some slices of your probabilistic atlas (intensities and label probabilities).
- Tissue models.