Medical Image Registration and Applications
Lab 1: Intensity Based Image Registration

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R. Martí and S. González-Villà

1 Introduction

Image registration is the procedure consisting of aligning an unregistered image (also called moving image) into a template image (also called fixed image) via a geometric transformation. This problem is usually addressed as presented in Fig. 1. An iterative procedure takes place to infer the geometric transformation (parametric or non-parametric) via an optimizer, which maximizes the similarity between the two images.

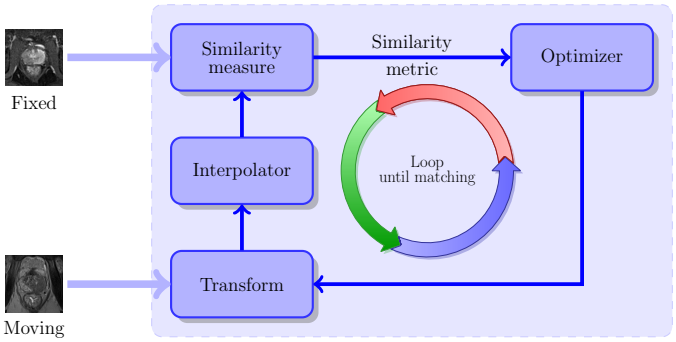

Figure 1: Typical framework involved to solve the registration problem.

The aim of this lab is to be familiar with the different components of a typical image registration framework. A fully working registration framework is provided in the notebook attached, implementing a rigid registration algorithm which minimises the sum of squared distances (SSD). Figure 2 shows an example of execution of the framework.

In this lab you will learn:

- Understand the concept and components of an image registration framework.
- Modify the framework to incorporate:
  - Normalised cross-correlation and normalized gradient correlation as new similarity metrics.
  - Affine transformation.
  - Multi-resolution framework.

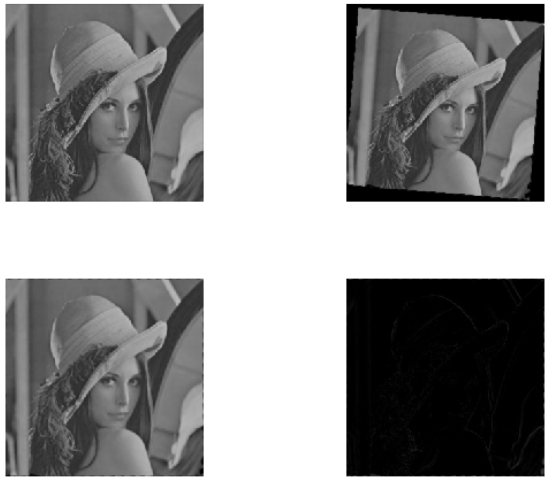

Figure 2: Example of image registration using SSD and an affine transformation. Fixed and moving images (top row) and registered moving and its difference with fixed (bottom row)

2 Registration framework

Read and understand the provided notebook and answer the following issues:

- Identify each of the components of an image registration framework, state their type and where they can be found (function name and line number).
- What is the function of the `scale` vector?
- Where is the center of rotation of the transformation?

3 Similarity metric. Normalised Cross-correlation

Add a new similarity metric to framework: normalised cross-correlation (NCC). Implement the NCC metric for intensity and gradient (NCC and gradient NCC).

4 Transformation. Affine transformation

Modify the framework to be able to deal with full affine 2D transformations. Justify how you initialise the transformation.

5 Multi-resolution.

Implement the above modifications in a multi-resolution registration framework. The number of resolutions should be a parameter of the framework, discuss how each resolution is initialised. Justify the benefits of multi-resolution in terms of computation time and/or accuracy of the final result, compared to a single resolution.

Submission

Edit and modify the provided notebook to contain:

- Explanation of the registration framework and its components.
- Answers to the implementation aspects requested in Sections 1-5 (Questions 2-6 in the notebook).
- Registration results using brain1.png, brain2.png, brain3.png, and brain4.png with the different combinations of the registration framework: different metrics, transformations and multi-resolution levels. For selected (representative) cases, plot the metric against iterations, computation time, registration results and final error (propose a quantitative error measure).
- Code containing
  - Intensity and gradient NCC similarity metric.
  - Affine transformation.
  - Multi-resolution.