Biomechanics constraint registration of thorax CTs for longitudinal analyses

Project Management and Software Development for Medical Applications

General Info
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Project Abstract
The CoViD-19 pandemic required great efforts by medical personnel treating infected patients. Many patients were hospitalized for a long period of time, while multiple CT of the thorax were acquired. Yet due to the lack of available infrastructure, changes images were only considered qualitatively. Comparing longitudinal CT quantitatively at voxel-level may be very valuable to understand the progression of the disease. The goal of the project is to develop a robust registration algorithm to align CTs taken at different time frames for CoViD-19 progression analysis.

Background and Motivation
The analysis of CoViD-19 disease progression is still an open research question. It requires the segmentation (of pathologies and anatomical structures) and the registration of CTs acquired at different time points. The voxel-wise progression analysis is believed to be more accurate than global (i.e. on the full lungs) analysis. However, it is only meaningful if the registration is robust, because it would ensure that corresponding areas of the lungs are compared. In this project, the registration algorithm will use the segmentation map of the anatomies to enforce the alignment between rigid or semi-rigid structures (i.e. ribs and airways), whereas soft tissue (i.e. the lungs) can be deformed to certain extent. The use of the segmentation map will help the algorithm in deforming only those structures that can actually be deformed, as well as avoiding errors in the registration due to the difference appearance of the lungs caused by the progressing infection [1].

Student's Task Description
The student will first start by implementing a conventional registration algorithm based on the CT (baseline). The student will then propose new ones based on the label map of the anatomical structures. The CTs and labels maps will be provided [2].
The main part of the project will consist in integrating the difference between the two label maps into the CT registration loss. In practical terms, the algorithm will:

1. Perform one iteration of the registration of CT1 and CT2
2. Deform LabelMap2 with the transformation computed before
3. Compute the dice score between LabelMap1 and the deformed version of LabelMap2
4. The similarity metric between CT1 and deformed CT2, the dice score between LabelMap1 and LabelMap2, as well as other metrics to keep rigidity will be combined and use to update the next step of the registration algorithm.

Prerequisites
- Knowledge of Medical Image Processing
- Good programming skills in Python
- Knowledge of Python packages for medical image analysis such as SimpleITK is beneficial

References
[1] https://www.elsevier.es/en-revista-radiologia-english-edition--419-pdf-S2173510721000033
[2] https://arxiv.org/abs/2208.05868