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Matching of airways using image registration

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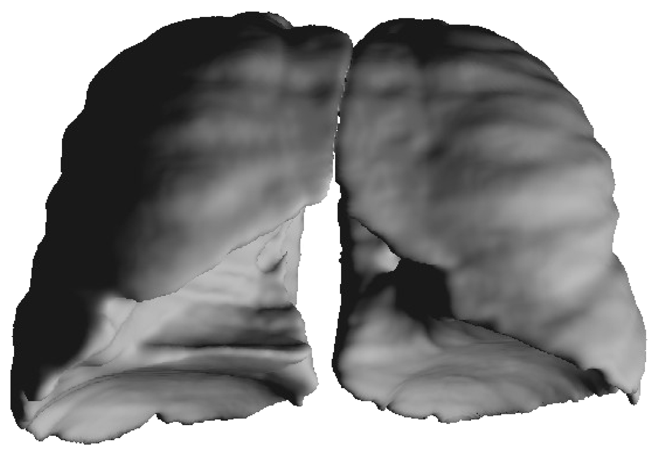
Introduction

Computed Tomography (CT) imaging has become a useful tool to investigate airway pathology, however automated analysis is still very difficult. A key issue is how to conduct comparable measurements in an environment which is varying both dynamically (caused by the effects of inspiration, age, disease, etc.) and biologically. In the work detailed in this poster, the use of image registration for matching airway branches at an intra subject level has been explored. The underlying method allows automated repeated measurements of individual airway segments, and is currently being used for longitudinal analysis of airway abnormality, as well as investigations into the effects of inspiration and age on airway dimensions.

Method

The approach of the method, detailed in the following sections, can be outlined as follows:

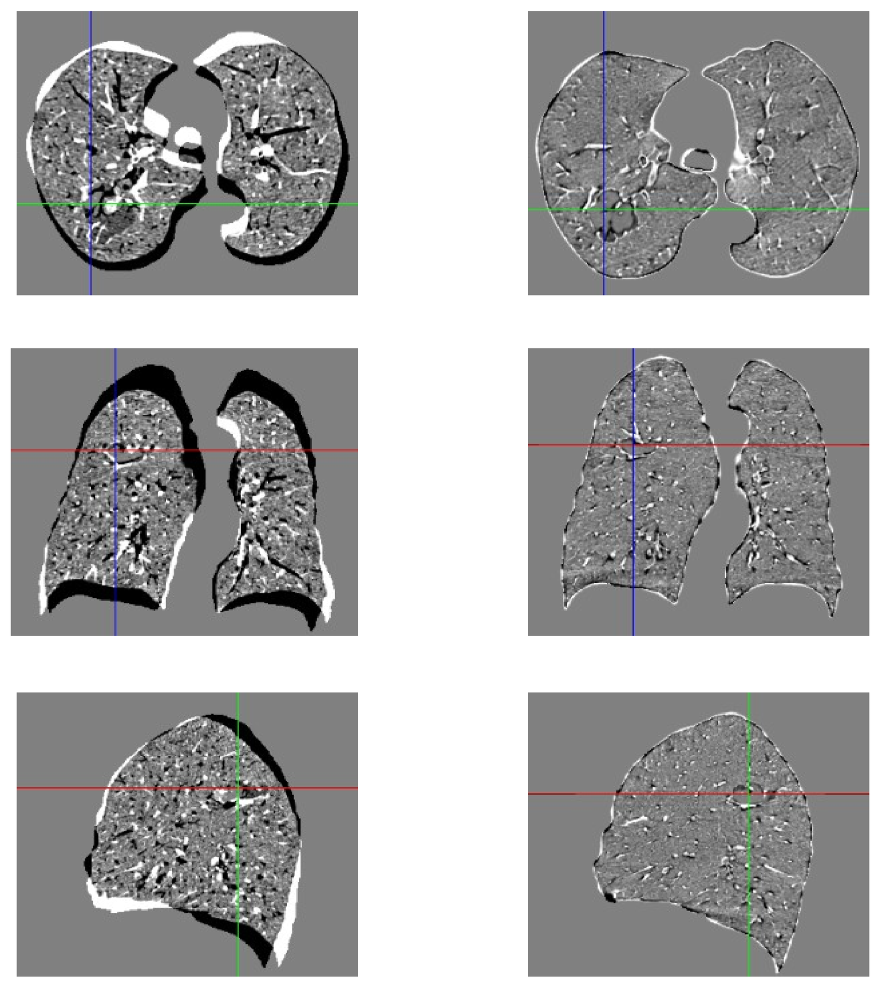
1. Lungs were segmented from the CT images.
2. All images of a given subject were registered.
3. The airway surfaces were segmented.
4. The branch centerlines were extracted from the result of 3.
5. The branch centerlines were matched within the common coordinate system defined by the result of 2.



Figur 1: Lung segmentation
Extracted using the region growing method described in [1]

Registration of the Lung CT images

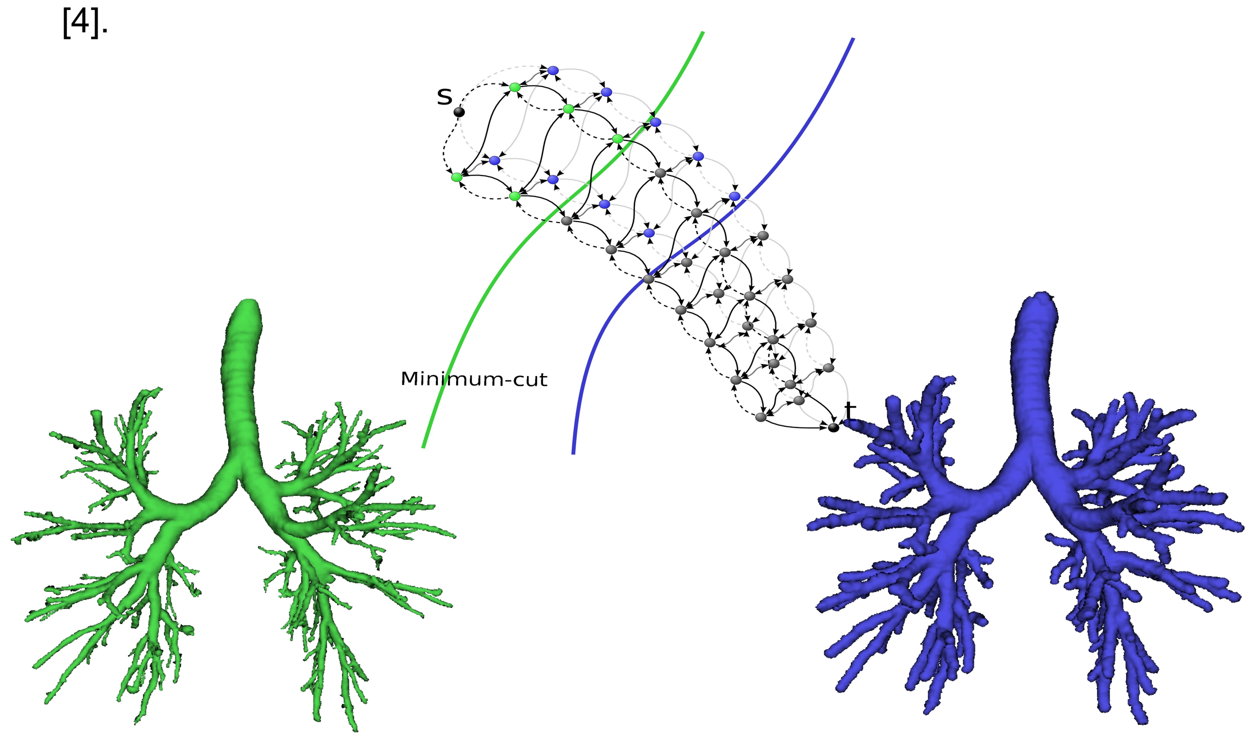
Lung CT image registration is difficult because image intensities vary between scans due to differences in inspiration level. The used method [2] incorporates a tissue appearance model based on the assumption of preservation of total lung mass, which makes it significantly better at handling differences in inspiration level.



Figur 2: Lung CT registration, two scans of the same subject
Left: differences before registration, right: after registration with the proposed method.

Segmentation of the Airway surfaces

Extraction of the airway surfaces is accomplished by first using a locally optimal path based approach [3] to find the airway tree, and then building an optimal surface graph designed to find the interior and exterior surface [4].



Figur 3: Airway surface segmentation
Left: interior surface, top: optimal surface graph, and right: exterior surface

Matching of airway branches

Airway centerlines and branch generations were extracted from the airway tree with a front propagation method, as described in [5]. Centerlines common to a given subject, were then moved to the shared coordinate system defined by the image registration process. This allows direct matching of branches based on distance and angles alone, and corrections to each centerline, such as for instance in the case of missing bifurcations or spurious branches, was made using majority voting [6].

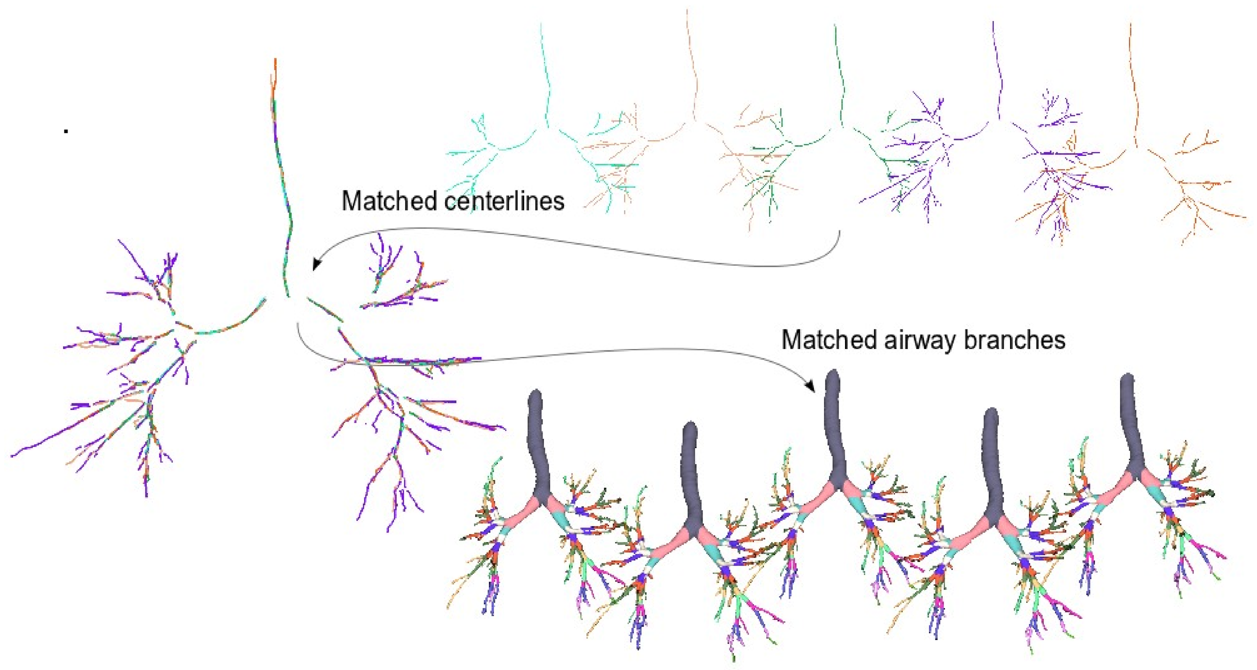


Figure 4: Process of matching airway branches
From scans at 5 different time points.

Data

Subsets of the data from the Danish Lung Cancer Screening Trial (DLCST) [7] was used in the work. 4104 participants were included, 2052 received annual CT and spirometry for 5 years.

- Low dose CT, resolution: 0.78 mm x 0.78 mm x 0.78 mm.
- At high risk of Chronic Obstructive Pulmonary Disease (COPD).

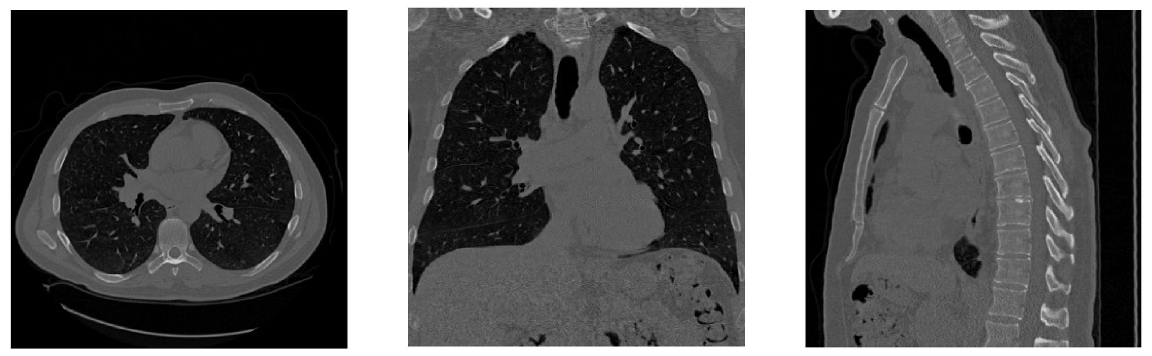
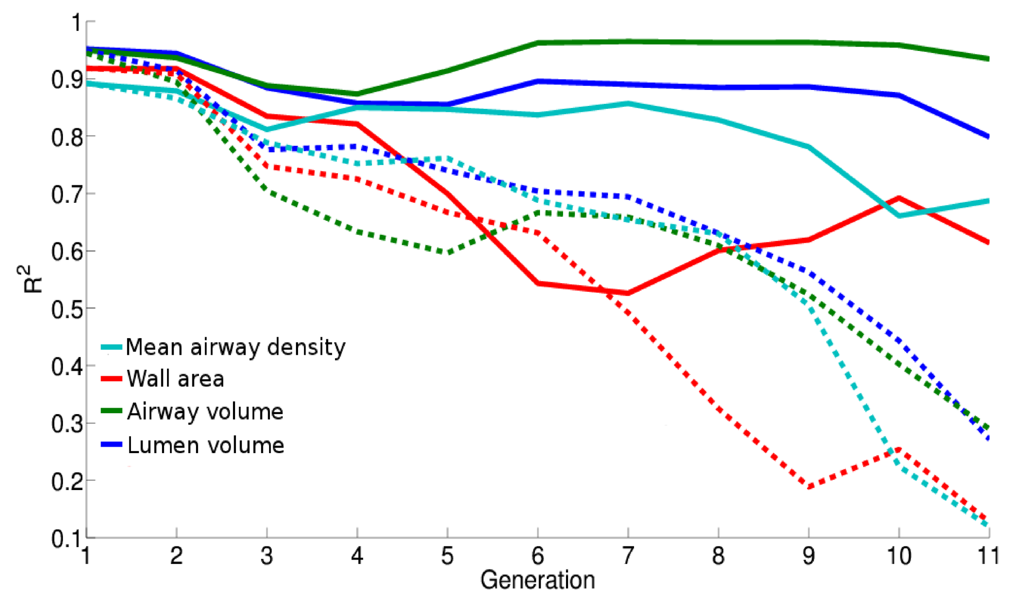


Figure 5: Axial, coronal and sagittal views of a CT image from the trial.

Results

Longitudinal measurements of airway abnormality

The method results in increased reproducibility when measurements are restricted to branches found in each scan, as figure 6 shows.



Figur 6: Reproducibility of airway abnormality measurements
Dashed lines: averages over all branches, complete lines: restricted to matched branches.

An annual decrease in density and increase in volume of the airways ($p < 0.001$) was found. The annual decrease in density was significantly negatively correlated with a decrease in lung function of the subjects diagnosed with COPD at baseline ($p < 0.05$) [6].

COPD and Airway distensibility [to be submitted]

Airways are known to be held in place by alveolar attachments and are likely expanding and contracting during the inspiration cycle following the surrounding lung parenchyma to some degree. The method allows quantification of how much and whether this distensibility is affected by the destruction of parenchyma with disease.

Figure 7 shows the distensibility, of airways grouped in quintiles by airway lumen diameter. Distensibility is defined as the slope of the relative expansion of the airway lumen diameter to the relative expansion of the cube root of the lung volume

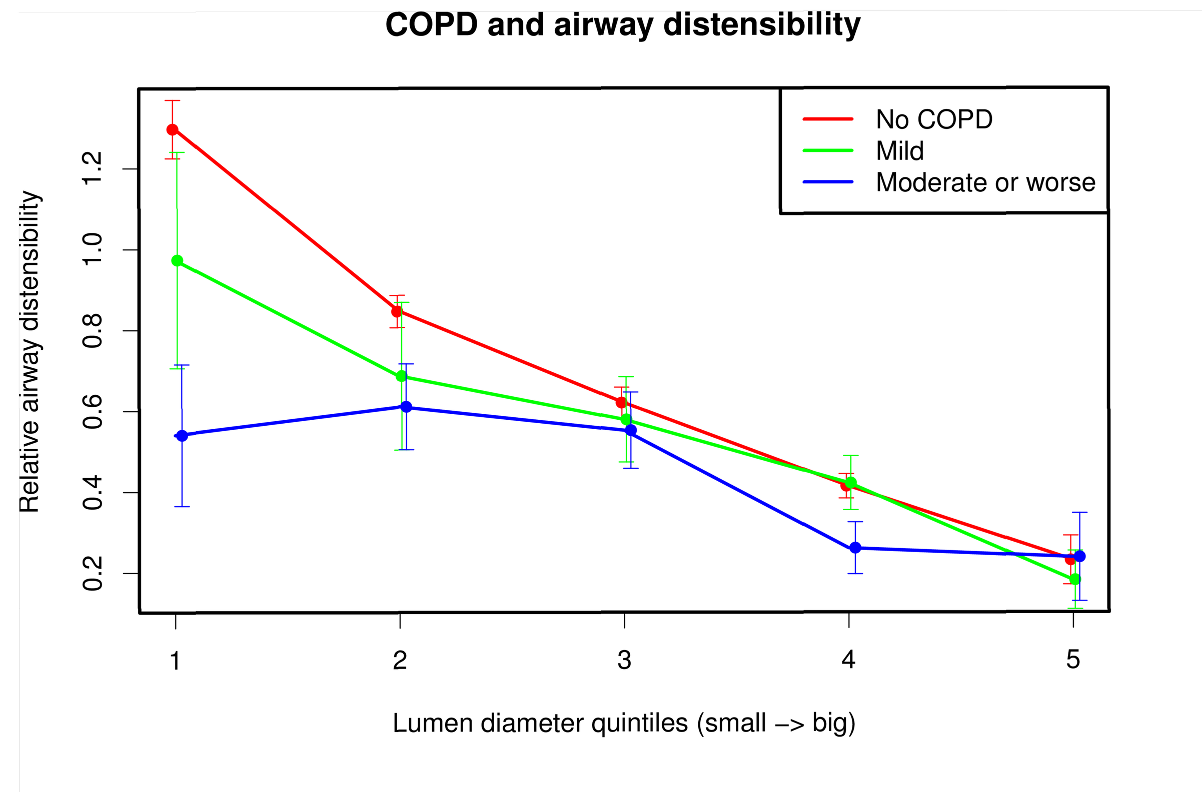


Figure 7: Airway distensibility by COPD severity and airway size
Smaller and healthier airways are more distensible.

For instance a value less or more than one means the diameters of the airways in this particular group expand and contract less or more than the surrounding tissue. The plot reveals that bigger airways are more rigid than smaller airways and that COPD, decreases distensibility.

Conclusion and dicussion points

- Increased reproducibility, possibly increasing the statistical power of longitudinal airway abnormality analysis.
- Airway distensibility decreases with airway size and COPD severity.
- What are the possibilities of using the method to develop models describing how airway dimensions are affected by inspiration level, age, gender, disease etc?
- Litterature says: Airway lumen narrow with COPD and airway wall thickens. But perhaps what is measured is more a lack of expansion with inspiration?

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References

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