PhD Thesis title: 'Image analysis methods for diagnosis of diffuse lung disease in multi-detector computed tomography'

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ABSTRACT:
Image analysis techniques have been broadly used in computer aided diagnosis tasks in recent years. Computer-aided image analysis is a popular tool in medical imaging research and practice, especially due to the development of different imaging modalities and the ever increasing volume of image data. Image segmentation, a process that aims at identifying and separating regions of an image, is crucial in many medical applications, such as in identification (delineation) of anatomical structures and pathological regions, providing objective quantitative assessment and monitoring of the onset and progression of the disease. Multi-detector CT scanners allow acquisition of volumetric datasets with almost isotropic voxels, enabling visualization, characterization and quantification of the entire extent of lung anatomy, thus lending itself to characterization of Interstitial Lung Diseases (ILDs), often characterized by non uniform (diffuse) distribution in the lung volume. Interpretation of ILDs is characterized by high inter- and intra- observer variability, due to the lack of standardized criteria in assessing its complex and variable morphological appearance, and it is further complicated by the increased volume of image data being reviewed. Computer-Aided Diagnosis schemes that automatically identify and characterize radiologic patterns of ILDs in CT images have been proposed to improve diagnosis and follow-up management decisions. These systems typically consist of two stages. The first stage is the segmentation of the left and right Lung Parenchyma (LP) regions, a process resulting from lung field segmentation and vessel tree removal, while the second stage regards classification of LP into normal and abnormal tissue types. The segmentation of Lung Field (LF) and vessel tree structures are crucial preprocessing steps for the subsequent characterization and quantification of ILD patterns. Systems proposed for identification and quantification of ILD patterns have mainly exploited 2D texture extraction techniques, while only a few have investigated 3D texture features. Specifically, texture feature extraction methods that have been exploited towards lung parenchyma analysis are: first order statistics, grey level co-occurrence matrices, gray level run length matrices, histogram signatures and fractals. The identification and quantification of lung parenchyma into normal and abnormal tissue type have been achieved by means of supervised classification techniques (e.g. Artificial Neural Networks, ANN, Bayesian classifier, linear discriminant analysis and k-Nearest Neighbor algorithms). However, the previously proposed identification and

quantification schemes in- corporate preprocessing segmentation algorithms, effective on normal patient data. In addition the effect of the preprocessing stages (i.e. segmentation of LF and vessel tree structures) on the performance of ILD characterization and quantification schemes has not been investigated yet. Furthermore, the complex interaction of such automated schemes with the radiologists remains an open issue. The present thesis deals with identification and quantification of ILD in lung CT. It describes a computer aided ILD quantification scheme based on optimized pre-processing steps, by exploiting 3D texture feature extraction techniques and supervised and unsupervised pattern classification schemes to derive 3D disease segments. The specific objectives of the thesis were focused on:

- Development of LF segmentation algorithms adapted to pathology.
- Development of vessel tree segmentation adapted to presence of pathology.
- Development of ILD identification and quantification algorithms.
- Investigation of the interaction of an ILD identification and quantification scheme with the radiologist, by an interactive image editing tool.

Both 2D and 3D texture-based methods proposed in this study outperformed gray level based methods, suggesting that gray level information is not sufficient to deal with ILD affecting lung parenchyma. The 3D texture-based lung field segmentation method also demonstrated promising results enhancing the potential of texture-based approaches towards computer-aided diagnosis of the pathological lung. The proposed vessel tree segmentation algorithm reduced the number of false positive indications and improved reticular pattern quantification when used as a pre-processing step.

Two schemes for the automated quantification of ILD patterns in CT of the lung were proposed. The first one is based on supervised segmentation and the second one combines supervised and unsupervised segmentation approaches. Both methods yielded good results regarding quantification of reticular patterns, with the hybrid method achieving better results in terms of false positive fraction index in the case of ground glass pattern quantification.

Although direct comparison of the method’s performance with previously reported studies is not feasible, due to lack of available reference data sets, results in terms of volume overlap are promising.

Finally, the current thesis focused on investigating the interaction of radiologist with the automated ILD quantification scheme, by means of an interactive image-editing tool. The analysis demonstrated that radiologists have limitations in disease extent quantification while, when combined with automated quantification systems, their performance is enhanced.

References to author publications that relate specifically to the dissertation:

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