Analyses of lung structure on computed tomography in patients with chronic lung diseases using persistent homology

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Abstract

Lung structural alteration directly affects lung function that is closely associated with symptoms and prognosis in patients with chronic lung diseases. Thus, rigorous structural evaluation using medical imaging such as chest computed tomography (CT) is critical for better management of these patients. There are unmet needs 1) to segment radiographic abnormalities such as regions with fibrosis and emphysema in the lungs, and 2) to extract morphological characteristics of a segmented target in relation to clinical information. This study developed two homological approaches including pixel value-based persistent homology and distance-based persistent homology. In pixel value-based persistent homology, we have obtained a pair of CT values (=pixel values) at which each homological feature appeared (birth) and disappeared (death) by sweeping the threshold levels from higher to lower CT values on volumetric CT data. In distance-based persistent homology, we have extracted an airway tree from volume CT data, generated a distance map from the centerline of the airway tree lumen, and obtained a pair of distances at which each homological feature appeared and disappeared by sweeping the thresholds of distance. These two approaches allow for robust segmentation of fibrosis regions in patients with idiopathic pulmonary fibrosis (IPF) and quantification of lumen irregularity of the airway tree in patients with chronic obstructive pulmonary disease (COPD).