Chapter 7
Techniques for the Automated Segmentation of Lung in Thoracic Computed Tomography Scans

William F. Sensakovic
The University of Chicago, USA

Samuel G. Armato III
The University of Chicago, USA

ABSTRACT

Computed Tomography (CT) is widely used to diagnose and assess thoracic diseases. The improved resolution of CT studies has resulted in a substantial increase of image data for analysis by radiologists. The time-consuming nature of this analysis motivates the application of Computer-Aided Diagnostic (CAD) methods to assist radiologists. Most CAD methods require identification of the lung within the patient images, a preprocessing step known as "lung segmentation." This chapter describes an intensity-based lung segmentation method. The segmentation method begins with simple thresholding, and several image processing modules are included to improve segmentation accuracy and robustness. Common segmentation difficulties are discussed and motivate the inclusion of each module in the lung segmentation method. These modules will include brief explanations of common techniques (e.g., morphological operators) in addition to novel techniques developed specifically for lung segmentation (e.g., gradient correlation filters).

INTRODUCTION

Computed Tomography (CT) of the thorax is used to diagnose and assess numerous thoracic diseases such as mesothelioma, emphysema, pulmonary embolism, and lung nodules (Armato & Sensakovic, 2004; Morgan, 1992; Mastuani, MacMahon, & Doi, 2002; Sensakovic,, et al., 2011; Zhou, et al., 2005). The availability of multidetector-row, fan-beam, and cone-beam CT scanners has improved image resolution and decreased scanning time, thus expanding the role

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of CT in the diagnostic assessment of patients. The improved resolution has resulted in substantially larger amounts of image data that must be analyzed by the radiologist or clinician. It is the tedious and time-consuming nature of this data analysis that has motivated the development of Computer-Aided Diagnostic (CAD) methods to assist radiologists in the evaluation of CT scans.

CAD methods that are applied to CT scans of the thorax usually require identification of scan voxels that comprise the lung (i.e., lung segmentation). The purpose of lung segmentation is threefold. First, many thoracic diseases such as nodules and emphysema are located in the lung. Lung segmentation allows a CAD method or image-guided therapy system to focus on analyzing only those voxels that comprise the lung, thus reducing the potential for errors (e.g., misdiagnosis of aortic calcification as a lung nodule). Further, limiting processing to the lungs greatly reduces computation time, because the lungs occupy only a fraction of the total thoracic CT scan. Second, the lungs are prominent, high-contrast structures centrally located within the thorax and thus may be used as guides for the segmentation of other structures of interest such as the heart or pleura (Sensakovic, 2010). Finally, lung segmentation may be useful for image data visualization. The three-dimensional (3D) display of CT scans is an area of rapid development, and lung segmentation would be required in a situation where, for example, a volume-rendered version of the lung parenchyma is desired as a visual aid for surgical planning (Wei, Hu, MacGregor, & Gelfand, 2006).

Lung segmentation must be accurate because abnormalities such as lung nodules may exist at the extreme periphery of the lungs. If the entire lung is not segmented, such abnormalities will be lost to subsequent analyses (Armato & Sensakovic, 2004). Quantitative assessment of lung volume (Sensakovic, Armato, Starkey, Kindler, & Vigneswaran, 2010) is a means of assessing several diseases, and inaccurate measurements could result in incorrect assessment. Finally, segmentation of pleural disease will often use the lung segmentation to establish the boundary of the pleura (and thus the disease boundary). Inaccurate segmentation of the lung will result in an incorrect segmentation (and assessment) of pleural disease (Sensakovic, 2010).

Lung segmentation in CT scans is one of the most extensively researched areas in medical image processing (Sluimir, et al. 2006). The low density of lung parenchyma compared with surrounding soft tissue translates into high contrast on CT, which in turn facilitates the use of several image processing techniques such as histogram thresholding (Armato & Sensakovic, 2004), active contours (Cohen, 1991; Kass, Witkin, & Terzopoulos, 1988), models (Brown, 1997), and graph cuts (Massoptier, 2009). This chapter describes an intensity-based lung segmentation method. The segmentation method begins with simple thresholding, and several image processing modules are included to improve segmentation accuracy and robustness. Common segmentation difficulties are discussed and motivate the inclusion of each module in the lung segmentation method.

OVERVIEW OF THE LUNG SEGMENTATION METHOD

The lung segmentation method assumes that the thorax and airway (i.e., trachea and bronchi) have been previously segmented (Sensakovic, 2010; Tschirren, Hoffman, McLennan, & Sonka, 2005). The lung segmentation method begins by taking the patient CT scan and removing all voxels outside the segmented thorax. This decreases the probability of errors by removing non-anatomic voxels such as the CT scanning table and exterior devices. The airway has Hounsfield Units (HU) similar to lung since both structures are filled with air, thus to keep airway from being incorrectly included in the final lung segmentation, the airway voxels are removed using the segmented airway. An intensity threshold of (-10000 HU, -200 HU)

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