Abstract

Chest X-ray radiography (CXR) has long served as the frontline imaging modality deployed for the detection of pulmonary disorders. Despite the modality's widespread clinical utility, the diagnostic efficacy of radiography for the detection and diagnosis of pulmonary diseases is severely hindered by the intrinsic physical limitation of the X-ray absorption contrast mechanism. The early manifestation of many pulmonary disorders involves the destruction, damage, or filling of the alveoli with fluids, immunological agents, and lesions prior to the onset of clinical symptoms. These underlying structural and physiological changes to the pulmonary anatomy result in an increase of X-ray attenuation by only a few percent. The low contrast generated between diseased and healthy pulmonary tissue can be easily obfuscated by the presence of anatomical noise or the superimposition of other anatomical structures along the X-ray beam direction.

The aim of this thesis is to construct, optimize, and evaluate a novel multi-contrast chest X-ray radiography prototype system to address the limitations associated with conventional X-ray radiography. Multi-contrast X-ray imaging leverages the wave nature of X-rays to simultaneously generate information regarding the absorption, refraction, and small-angle scattering of X-rays. The small-angle scattering mechanism has demonstrated the capacity to probe the microstructures of the lungs and generate a strong image signal of alveolar air interfaces. However, when the alveoli become filled, damaged, or destroyed, the small-angle scattering signal is extinguished. It is for this reason that multi-contrast X-ray imaging is hypothesized to enhance the utility of X-ray radiography. The first key topic of this thesis work is the design and construction of a clinically compatible multi-contrast prototype system. Following the system construction, a fast scanning beam acquisition scheme is implemented to enable imaging of the entire chest within a single breath-hold. The interferometric and clinical imaging performances are then optimized for a variety of clinical imaging scenarios. To conclude this thesis, the potential for multi-contrast imaging to enhance the diagnostic efficacy of X-ray radiography is evaluated through phantom and animal imaging studies.