Toward a clinical Multi-Contrast X-ray Imaging System: Novel solutions to address key technical challenges

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Recently, the Talbot-Lau interferometer based multi-contrast x-ray imaging method has attracted a lot of research interests. From the same image acquisition, this new imaging method can provide three sets of images with three endogenous contrast mechanisms: absorption contrast, differential phase contrast (DPC), and dark-field contrast. Studies have shown that the DPC imaging may provide superior contrast sensitivity for certain types of soft tissues, and dark-field imaging is particularly sensitive to certain fine structures such as microcalcifications in the breast. Therefore, multi-contrast x-ray imaging provides a potential opportunity to address some of the inherent limitations of the conventional x-ray absorption contrast imaging, for example, the relatively low soft tissue contrast sensitivity. However, the current implementation methods of multi-contrast x-ray imaging also have several technical challenges that need to be addressed before its full clinical potential can be demonstrated. The main challenges include the prolonged imaging time and the relatively low radiation dose efficiency for the absorption contrast imaging.

In this dissertation, we mainly focus on addressing these key technical challenges. The overarching objects of the project are: (1) to reduce the image acquisition time of multi-contrast x-ray imaging system; (2) to improve the radiation dose efficiency of the absorption imaging component in multi-contrast x-ray imaging system; and (3) to maximize the radiation dose efficiency of DPC imaging component in multi-contrast x-ray imaging system. Several innovative strategies have been introduced to accomplish the above objectives. The two main outcomes of this thesis project are: (i) the image acquisition time of multi-contrast x-ray imaging has matched that of the conventional absorption contrast x-ray imaging, and (ii) the absorption contrast component of multi-contrast x-ray imaging has been shown to achieve similar dose efficiency compared to the conventional absorption contrast x-ray imaging. Furthermore, the dark-field tomosynthesis imaging has been demonstrated to mitigate the structure overlapping problem and improve the imaging performance of low attenuating materials and fine structures inside the objects. Finally, the DPC component of multi-contrast imaging has also been optimized, such that it provides the maximal amount of complementary image information without additional radiation dose. These innovative solutions developed in this thesis work should greatly accelerate the translations of multi-contrast x-ray imaging to clinical applications in the future.