A Comparison of Tissue Phase-Retrieval Approaches for Medical X-ray Imaging

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Retrieval of the tissue phase-maps has great potential for improving tissue contrast and achieving quantitative imaging for tissue characterization. The robustness of a phase-retrieval approach is of critical importance for clinical imaging applications. On the one hand, the limits on permissible organ radiation doses make acquired images much noisier than that encountered in other non-clinical applications. On the other hand, the phase changes of pathological tissues are small and the diagnosis accuracy would be very much vulnerable to the phase-retrieval errors. For example, while a 4cm-thick breast tissue generates about 700 radians, phase-shift difference between a 5mm-size invasive ductal carcinoma in breast and surrounding parenchyma is of only about 5 radians for 60 keV x-rays. In this work the robustness of phase-retrieval from a single image based on the phase-attenuation duality is compared to its performance with that with the popular TIE-based phase-retrieval approaches for 60-keV x-rays by means of computer simulations. The imaged object is a hypothetical breast of 4 cm thick with very low tissue attenuation contrasts 0.83% for 60 keV x-ray, this attenuation contrast corresponds to that between a 5mm-size invasive ductal carcinoma and surrounding normal breast parenchyma. We assumed a quantum noise 5% associated for low dose imaging. With a single phase-contrast image and our duality-based approach a breast phase-map was retrieved with an average relative phase-error of 0.11%. For the TIE-based phase retrieval approach, an additional image acquired at the contact mode with an anti-scatter grid was simulated. With these two images (one attenuation image and one phase-contrast image) the breast phase-map was retrieved by the TIE-based approach. Since TIE-based phase-retrieval suffers from intrinsic instability, the Tikhonov regularization was employed. In spite of increased radiation dose to breast (due to two acquired images needed), phase-error with the TIE-retrieved breast phase-map is 0.91%, and the tissue-contrast distortion in TIE-retrieved breast phase map is prominent. Hence the phase-attenuation duality-based approach is superior to TIE-based approaches for tissue phase retrieval with hard x-rays. Finally, the phase-contrast tomography with these approaches will be compared.

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