PhD Thesis title: 'Modeling digital breast tomosynthesis imaging systems for optimization studies'

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ABSTRACT:

Digital breast tomosynthesis (DBT) is a new imaging modality for breast imaging. In tomosynthesis, multiple images of the compressed breast are acquired at different angles, and the projection view images are reconstructed to yield images of slices through the breast. One of the main problems to be addressed in the development of DBT is the optimal parameter settings to obtain images ideal for cancer detection. Since it would be unethical to irradiate women multiple times to explore potentially optimum geometries for tomosynthesis, it is ideal to use a computer simulation to generate projection images. Existing tomosynthesis models have modeled scatter and detector without accounting for oblique angles of incidence that tomosynthesis introduces. Moreover, these models frequently use geometry-specific physical factors measured from real systems, which severely limits the robustness of their algorithms for optimization.

The goal of this dissertation was to design the framework for a computer simulation of tomosynthesis that would produce images that are sensitive to changes in acquisition parameters, so an optimization study would be feasible.

A computer physics simulation of the tomosynthesis system was developed. The x-ray source was modeled as a polychromatic spectrum based on published spectral data, and inverse-square law was applied. Scatter was applied using a convolution method with angle-dependent scatter point spread functions (sPSFs), followed by scaling using an angle-dependent scatter-to-primary ratio (SPR). Monte Carlo simulations were used to generate sPSFs for a 5-cm breast with a 1-cm air gap. Detector effects were included through geometric propagation of the image onto layers of the detector, which were blurred using depth-dependent detector point-spread functions (PRFs). Depth-dependent PRFs were calculated every 5-microns through a 200-micron thick CsI detector using Monte Carlo simulations. Electronic noise was added as Gaussian noise as a last step of the model. The sPSFs and detector PRFs were verified to match published data, and noise power spectrum (NPS) from simulated flat field images were shown to match empirically measured data from a digital mammography unit.

A novel anthropomorphic software breast phantom was developed for 3D imaging simulation. Projection view images of the phantom were shown to have similar structure as real breasts in the spatial frequency domain, using the power-law exponent β to quantify tissue complexity.

The physics simulation and computer breast phantom were used together, following methods from a published study with real tomosynthesis images of real breasts. The simulation model and 3D numerical breast phantoms were able to reproduce the trends in the experimental data. This result demonstrates the ability of the tomosynthesis physics model to generate images sensitive to changes in acquisition parameters.

References to author publications that relate specifically to the dissertation:

B. Lau, I. Reiser, and R. Nishikawa, Microcalcification detectability in tomosynthesis," Proceedings of SPIE 6913, 69134L, 2008.

B. Lau, I. Reiser, and R. Nishikawa, The Effect of Variable Exposure Distribution On Microcalcification Detectability in Tomosynthesis," Med. Phys. 35(6), p. 2978, 2008.

B. Lau, P. Bakic, I. Reiser, A. K. Carton, A. Maidment, and R. Nishikawa, An Anthropomorphic Software Breast Phantom for Tomosynthesis Simulation: Power Spectrum Analysis of Phantom Reconstructions," Med. Phys. 37(6), p. 3473, 2010.

P. Bakic, B. Lau, A. Carton, I. Reiser, A. Maidment, and R. Nishikawa, An Anthropomorphic Software Breast Phantom for Tomosynthesis Simulation: Power Spectrum Analysis of Phantom Projections," Proceedings of Digital Mammography, pp. 452-458, 2010.

B. A. Lau, I. Reiser, and R. M. Nishikawa, Issues in characterizing anatomic structure in digital breast tomosynthesis," Proceedings of SPIE 7961, Mar. 2011.

B. A. Lau, I. Reiser, R. M. Nishikawa, and P. R. Bakic, “A statistically defined anthropomorphic software breast phantom,” Med. Phys. 39(6), p 3375-3385, 2012