Abstract ID: 15853   Title: A Cascaded Systems Model for Imaging Performance and Task-Based Optimization in Dual-Energy Cone-Beam CT

Purpose: Optimization of dual-energy (DE) tomographic imaging performance is challenged by the vast number of parameters to be considered. This work establishes a quantitative framework for theoretical analysis of noise-power spectrum (NPS) and task-based detectability in DE cone-beam CT (DE-CBCT). The model is compared to experimental results and applied to task-based optimization of dual-kVp selection and minimization of radiation dose.

Methods: The model combines established methods for NPS propagation in DE imaging and CBCT, yielding a new framework for optimization of the DE-CBCT imaging chain. The resulting DE-CBCT NPS and noise-equivalent quanta (NEQ) were derived to compute the detectability index for a variety of tasks in contrast-enhanced musculoskeletal imaging. Theoretical calculations were validated against experimental measurements on a DE-CBCT bench simulating the geometry of a CBCT prototype under development for musculoskeletal radiology. Optimization parameters included kVp pair, added filtration, dose allocation, etc.

Results: The model provided tremendous insight in competing factors of DE-CBCT performance. DE contrast (e.g., signal difference in 1 mm Ca or iodine to soft-tissue) favored wide energy separation (e.g., [50/140] kVp) whereas NEQ degraded with kVp (e.g., maximized within the range considered at [65/100] kVp, with 0.6 mm Ag added to the latter). Detectability index quantitatively factored such tradeoffs in contrast and spatial-frequency-dependent noise along with the dose and imaging task – e.g., optimum at [65/105] kVp for a delta-function iodine detection task. The model provided a quantitative guide to optimizing a broad scope of factors that would be difficult to consider through experimentation alone.

Conclusions: A task-based cascaded systems model establishes a new, quantitative framework for systematic optimization of DE-CBCT imaging performance. The model combines established models shown to be of value in DE imaging and CBCT and should provide a valuable foundation for the development, optimization, and translation of high-quality DE-CBCT imaging techniques.

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