Noise and signal detection in digital x-ray detectors using the spatial definition of SNR

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ABSTRACT

For task specific evaluation of imaging systems it is necessary to obtain detailed descriptions of their noise and deterministic properties. In the past we have developed an experimental and theoretical methodology to estimate the deterministic detector response of a digital x-ray imaging system, also known as the **H** matrix. In this paper we have developed the experimental methodology for the evaluation of the quantum and electronic noise of digital radiographic detectors using the covariance matrix **K**. Using the **H** matrix we calculated the transfer of a simulated coronary artery constriction through an imaging system's detector, and with the covariance matrix we calculated the detectability (or Signal-to-Noise Ratio) and the detection probability. The eigenvalues and eigenvectors of the covariance matrix were presented and the electronic and quantum noise were analyzed. We found that the exposure at which the electronic noise equals the quantum noise at 90 kVp was 0.2 μR. We compared the ideal Hotelling observer with the Fourier definition of the SNR for a toroidal stenosis on a cylindrical vessel. Because of the shift-invariance and cyclo-stationarity assumptions, the Fourier SNR overestimates the performance of imaging systems. This methodology can be used for task specific evaluation and optimization of a digital x-ray imaging system.

Keywords: covariance matrix, **H** matrix, SNR, detectability, coronary

1. INTRODUCTION

In the past we have presented a method for estimating the **H** matrix of a digital detector, which can be used to evaluate its deterministic performance.[1–4] For a more complete description of a digital detector we should also characterize the quantum and electronic noise, which can be used to determine the signal-to-noise ratio (SNR) for a specific imaging task. This paper presents a method for estimating the covariance matrix, which describes the noise properties of the imaging system, and uses the **H** matrix determined in the past[4] to estimate the SNR for a signal known exactly, background known exactly detection (SKE/BKE) task. The Fourier-based methods we have used in the past to estimate the performance of imaging systems[5–9] make some limiting assumptions which we will explore here. By using the spatial definition of the SNR we calculate the detectability of a coronary vessel constriction as an example application of this methodology.

2. MATERIALS AND METHODS

2.1 Theory

2.1.1 Deterministic description of imaging systems

A digital image of $\mathrm{M}_x \times \mathrm{M}_y$ dimensions can be lexicographically arranged as an array $\mathbf{g}$ with $\mathrm{M} = \mathrm{M}_x \times \mathrm{M}_y$ elements. The equation of the expected image in the absence of noise using the **H** matrix, which maps a discrete object phase-space array $\mathbf{w}$ with N elements to the discrete image $\mathbf{g}$, is given by

$$\bar{\mathbf{g}} = \mathbf{H}\,\mathbf{w}\,. \tag{1}$$

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