Understanding noise power spectrum in light of human observer detection in Tomosynthesis

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Rationale:

The anatomical noise power spectrum of a mammographic image has been shown to obey a power law relationship by several investigators. This frequency distribution of the noise in the image, which captures the anatomical structure and variability of the breast, has been characterized by the parameter β or the slope of the power law spectrum. Researchers have predicted that lower anatomical structural noise as indicated by a lower value of β would indicate better abnormality detection performance. In our initial studies, we see that β varies with different acquisition parameters in digital breast tomosynthesis (DBT). We propose to investigate how β varies with DBT acquisition parameters and reconstruction methods. Our studies will also shed light to the extent to which β can characterize detectability via comparison with human observer studies.

Methods:

Anatomical variability is characterized via the noise power spectrum in literature as $\boldsymbol{NPS_a = \alpha f^{-\beta}}$, where NPS_a is the anatomical noise power spectrum in the region of the breast dominated by structural noise, f is the spatial frequencies represented and β is the slope of log-log plot of NPS_a. Regions of size 64x64 (17.28x17.28mm) are selected with 50% overlap in the breast region of simulated slices. A Hanning data taper is applied to reduce spectral leakage and then the power spectrum is calculated using a Fourier transform. The radially averaged noise power spectrum is then plotted on a log-log plot. The slope of linear portion of this plot represented by powers in the ranges of 0.15 – 0.7 cycles/mm is computed as the β of the region. An average β is then calculated from all the selected regions of the image.

Results:

We simulated projections using anthropomorphic breast phantoms generated by Bakic et al. at University of Pennsylvania, reconstructed these images and then calculated average β values for sets of images which were acquired and reconstructed using exact same strategies. Multiple strategies were examined in the complete study, which included varying project arcs (between 30° and 90°) and number of projections (between 3 and 51). Our preliminary results show that lower β values do not necessarily indicate signal detectability in DBT images. Studies included considerations of varying breast densities and noise levels as well.

Conclusions:

From our initial findings, it appears that lower β does not always imply better lesion detectability. An alternative use for the parameter β hinges on its attempt to capture anatomical structure of the entire breast. This could be still a valid application in virtual clinical trial like simulation platforms. Due to its dependence on acquisition parameters, the noise power spectra anatomical noise cannot be used as an indicator to predict performance of different modalities such as mammography, DBT and breast CT. Further investigations are underway to examine other aspects related to the image noise power spectrum that may control ultimate detectability.