Quantitative Comparison of Noise Texture Across CT Scanners From Different Vendors

We compared noise texture across CT scanners of different vendors by measuring the noise power spectrum (NPS) from images reconstructed many available kernels using filtered backprojection. The 2D NPS was calculated using an ensemble average of the Fourier transform of uniform regions of interest (ROI)^1.

\[ \text{NPS}(u, v) = \frac{d_x d_y}{N_x N_y} \cdot |F[I(x, y) - P(x, y)]|^2, \]

where ( ) denotes an ensemble average, \( d_x \) and \( d_y \) are pixel size in mm, \( N_x \) and \( N_y \) are the number of pixels in the x and y direction of the ROI, \( F[\cdot] \) denotes the Fourier Transform, \( I(x, y) \) is the pixel values of the ROI in Hounsfield Units (HU), and \( P(x, y) \) is a second order polynomial fit of \( I(x, y) \). The 2D NPS were normalized to have equal volume and then a radial average was taken to visualize the 2D NPS as function of just one spatial frequency. The NPS were further filtered by the human visual response function^2, \( V(\rho) \), to account for the variable perception of noise by a human observer at different spatial frequencies. The filtered NPS is given by

\[ \text{NPS}_\text{filtered}(f) = \text{NPS}_\text{measured}(f) \cdot |V(\rho)|^2, \]

\[ \rho = f \cdot \frac{\text{FOV} \cdot R}{2 \cdot 180}, \]

\[ V(\rho) = \left[ \eta \rho^{a_1} \cdot e^{-a_2 \rho^{a_3}} \right]^2, \]

where \( f \) is radial spatial frequency in cycles/mm, \( \rho \) is the radial spatial frequency in cycles/degree, \( \text{FOV} \) is the reconstructed field of view in mm, \( R \) is the viewing distance in mm, \( D \) is the size of the displayed image in mm, \( \eta \) normalized \( V(\rho) \) to one at its maximum value, and parameters \((a_1, a_2, a_3)\) are \((1.5, 0.98, 0.68)\). A viewing distance of 40 cm and a display size 30 cm were assumed when applying the human visual response function. Figure 1 shows the measured NPS for a few similar GE and Siemens kernels. The shaded region represents one standard deviation as calculated during the radial averaging.

![Figure 1: Images of the high contrast resolution (HCR) and low contrast resolution (LCR) sections of the ACR phantom with a plot of their corresponding filtered NPS curves.](image)

After calculating the filtered NPS, GE kernels were individually compared with Siemens kernels using the root mean square error (RMSE). The RMSE equation is essentially a point-by-point comparison between the two NPS curves. A small RMSE implies that the two NPS curves, and therefore the noise texture between their corresponding images, are similar. This comparison was done between all GE and Siemens kernels studied. The results of these comparisons are summarized by the color map in figure 2. A similar comparison using the difference in NPS peak...
location was done and those results are summarized by the color map in figure 3. A small peak difference implies similar kernels.

Figure 2: RMSE values between GE and Siemens kernels overlaid on a color map.

Figure 3: Peak difference values between GE and Siemens kernels overlaid on a color map.

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