SNR Estimation in Fast Dynamic Imaging Using Bootstrapped Statistics

M. J. Riffe[1], M. Blaimer[2], K. J. Barkauskas[1], J. L. Duerk[1,2], and M. A. Griswold[2]

[1]Dept. of Biomedical Engineering, Case Western Reserve University, Cleveland, OH, United States, [2]Dept. of Radiology, University Hospitals of Cleveland and Case Western Reserve University, Cleveland, OH, United States

Introduction: Evaluation of local signal-to-noise ratio (SNR) is essential for many image-based analyses. Novel pulse sequence technology for dynamic imaging, such as HYPR [1], requires an alternative to conventional SNR estimation methods, since the SNR can vary in unexpected ways over very small distances; the typical assumption of near constant noise level throughout the object of interest [2] no longer applies. Other methods [3] need some model of this noise behavior for accurate results. Here we propose a new technique that accurately estimates pixel-wise SNR using a single raw data set and collected noise data. Our method is based on bootstrap statistics. Estimates of the SNR statistics are derived by synthesizing multiple image repetitions by randomly reordering the collected noise data and combining it with the original raw data. This work validates the bootstrap statistics method by comparing its SNR estimation with conventional techniques and demonstrates its extension in HYPR angiography.

Methods: The bootstrap statistics method requires only two sets of raw data: encoded signal and sampled noise. The sampled noise is repeatedly and randomly reordered and then added to the raw data prior to reconstruction in order to simulate multiple acquisitions of the same data set. This yields a set of synthesized repetitions, which permit pixel-wise mean, variance and SNR computation. The accuracy of the bootstrap statistics method was evaluated in three trials, each of which was preceded by a noise scan. *Trial #1*: Simulated Shepp-Logan phantom and noise data were created in MATLAB, where estimated pixel-wise SNR was compared with the known phantom SNR. *Trial #2*: Cartesian FLASH series (fifty repetitions) of a stationary Gd-DTPA-doped phantom were collected, where one repetition was randomly selected as "image data" for the bootstrap statistics method, and the estimated pixel-wise SNR was compared to pixel-wise SNR using the entire stack of actual repetitions. *Trial #3*: Two repetitions of 32-channel Cartesian TrueFISP of the same Gd-DTPA-doped phantom were collected. Estimated pixel-wise SNR was compared to SNR calculated by the difference method [4]. *HYPR Application*: To show this method's application in fast dynamic HYPR imaging, SNR statistics for in vivo HYPR brain angiography (Frames=11, Readout = 256 pts, 23 projections per frame) were estimated using bootstrap statistics, and ROI analysis was performed on the anterior communicating artery and the sagittal sinus vein.

	Trial #1: Phantom Simulation	**Trial #2:** Time Series FLASH	**Trial #3:** 32 Channel TrueFISP
Bootstrapped	39.4 ± 6.5	42.2 ± 4.5	48.2 ± 5.3
Conventional	39.4 ± 3.1	44.1 ± 4.3	50.3 ± 6.5

Figure 1: SNR estimation by the bootstrap statistics method agrees with conventional techniques. Fifty synthesized repetitions were used for SNR estimation.

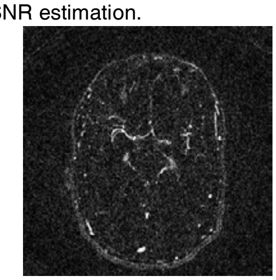

Figure 2: Arterial phase SNR map from a single slice of the HYPR angiogram.

Results: Figure 1 shows the SNR estimation results from each trial. Mean SNR across an ROI (100 pixels) was computed for comparison to conventional methods. The difference between SNR from conventional approaches and the bootstrap statistics method was negligible. The time course mean, noise, and SNR are calculated for an anterior communicating artery and a sagittal sinus vein in the HYPR example, shown in figure 3. As one can see, the noise level is not constant throughout the acquisition, and in fact shows significant correlation with the signal levels, resulting in a step-like change in SNR which does not simply follow the signal level.

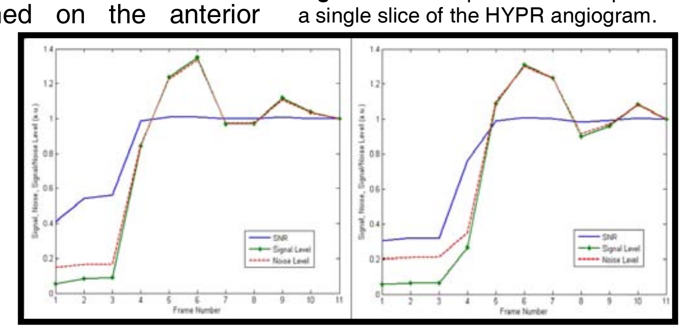

Figure 3: ROI SNR statistics were estimated for an anterior communicating artery (left) and a sagittal sinus vein (right) normalized to their values in the last frame. Significant correlation between signal and noise levels is revealed.

Discussion: In light of the close agreement in the imaging trials, the bootstrap statistics method estimates local image SNR as accurately as conventional methods when considering Cartesian-like acquisitions. Unlike existing approaches, bootstrap statistics method can estimate SNR even in rapid dynamic situations with a single noise scan and a single encoding of raw data. In its HYPR application, the bootstrap statistics method revealed pixel-wise signal-noise correlation, further confirming the non-traditional SNR scaling in HYPR.

References:

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