Spike noise removal in MR images using over sampling

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Introduction

MR images are reconstructed from K space raw data. Sometimes K space raw data can be corrupted with high amplitude value noise, resulting gross striation artifact. This noise is referred as spike noise. The causes of these spikes can be arcing, loose connection or other electrical/mechanical problems in system. Spike noise is difficult to diagnosis and usually it is cost and time consuming job to fix a spike noise issue

Previous methods can be categorized into two classes. One is based on imaging domain and the other is based on K space domain. In imaging domain, the most important point is to find a "homogeneous-material region" in the imaging FOV with an algorithm. The intensity variation in this region is believed to be mainly contributed by spike noise, not the imaging object. (1) (2) In K Space domain, the key point is to find a spatially varying threshold. Any data point that has a magnitude greater than that of the threshold value at that location will be replaced by a local complex average of the neighboring data points (3) or some other suitable data replacement scheme.

This abstract describes an imaging domain method. With over-sampling, high frequency region of image can be regarded as "homogeneous-material region". Any intensity in this region is believed to be mostly contributed by spike noise.

Over-sampling is widely used in current MR products. Usually, over-sampled data are directly filtered to avoid alias artifact in frequency direction. In method of this abstract, over-sampled data are used not only to avoid alias but also to find spike noise.

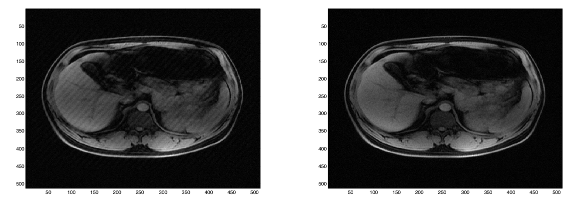
Methods

Spike noise is very short in time domain. It contains abundant high frequency information. But bandwidth of scanned object is limited and is determined by applied gradient pulse and size of object. In high frequency region of image, signal comes mostly from spike noise.

The detail method in this abstract can be described as following:

Suppose K space is acquired line by line and there is only one spike noise point in one acquisition.

1. Acquire one line with over-sampling in K space.
2. Apply 1D FFT to over-sampled data.
3. Adjust if there is spike noise by check signal from outer region.
4. If there is spike noise, using functions [1] [2] and [3] to get amplitude, phase and position of spike noise.
5. Remove Spike noise



Left image Right image

Fig 1. Left image: with artifact from spike noise; Right image: spike noise artifact is removed with method in this abstract

*Amp = (sum(mag(l))) / L * N* , where *mag(l)* is the magnitude of pixel value. [1]

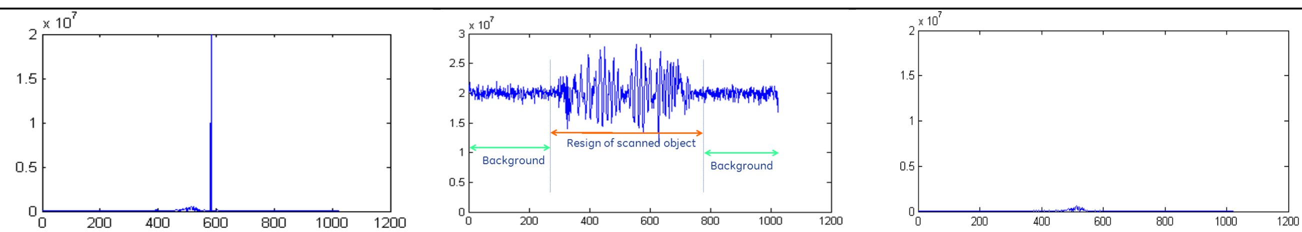
Phase = ph , where *ph* is the phase of the first pixel [2]

*Position = (dps * N) / (2*pi)* , where *dps* is the phase difference between 2 adjacent pixels. [3]

Results

See Left image in Fig 1. There is artifact from spike noise. The sampled points for read direction are 512. With over-sampling, total 1024 points are acquired. With method in this abstract, only one K space line has spike noise. Fig 2 (a) shows the K space line with spike noise. Fig 2 (b) shows the result of this line after 1D FFT. The signal in background region exceeds system noise level and is considered from spike noise. Using function [1],[2] and [3], the amplitude, phase and position of spike noise are calculated. After removing spike noise, the over-sampled data are shown in Fig 2 (c). After remove spike noise, the clean image is shown in right image of Fig 1

In this example, the over-sampled ratio is only 2. With current hardware, it is easy to reach higher over-sample ratio. Higher over-sampled ratio makes it easy to find the background region that contains only signal from spike noise.



(a) (b) (c)

Fig 2: (a) Over-sampled data with spike noise; (b) Image after 1D FFT. There is strong signal intensity in "background" region. It is from spike noise; (c) Over-sampled data after removing spike noise.

Discussion

With over-sampling, it is easy to find "background" that contains only noise and signal from spike noise. It is very convenient to utilize imaging domain method to detect spike noise and remove it. It is also possible to remove spike noise precisely from K space and leave the original K space data unaffected. Method in this abstract is to deal with data line by line. It is much simple than traditional method in 2D/3D image. The method in this abstract is not convenient for non-linear acquisition, such as spiral. If spike noise lasts longer, the frequency bandwidth of spike noise becomes narrower and the efficiency of method in this abstract becomes weaker.

References

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3. Foo, T.K.F. Grigsby, N.S. Mitchell, J.D. Slayman, B.E. SNORE: spike noise removal and detection, Medical Imaging, IEEE Transactions on, Volume: 13 Issue: 1, 133 – 136. This method is from GE ASL.