K-SPACE INFORMATION MAP

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Introduction

In MRI, empirical results show that the center of k-space, i.e. lower frequencies components, have more information than outer regions, in terms of producing a visually pleasant image (contrast). However, the exact form of the information density is unknown.
We developed a method to obtain a k-space information map, and apply it to brain slices. This map can give an idea on how the information is distributed in k-space. It can be used to determine sampling strategies for k-space and best way to undersample it, for instance.

Method

We use an entropy approach to make an information map from MRI images. Entropy is generally accepted as a useful measurement of information quantity. The entropy of a single image, H, defined as:

$$H = \sum \mathrm{P}_j \cdot \log\left(\mathrm{P}_j\right)$$

where P_j is the probability of occurrence of the j-th grey level in the entire image.
To find the information map, we calculated the entropy of each spatial frequency from a set of k-space maps, obtained from 500 images (256x256, FFE, transversal, T1 weighted, 0.5T) of a similar slice of the head from different clinical scans. We define the entropy of the i-th spatial frequency as:

$$E_i = \frac{\sum_1^M \mathrm{P}_{i,k} \cdot \log\left(\mathrm{P}_{i,k}\right)}{\log\left(M / Q_i\right)}$$

where $\mathrm{P}_{i,k}$ is the probability of occurrence of the k-th quantization level of the i-th frequency, and Q_i is the quantization step for the i-th frequency. The formula above normalizes the entropy taking into consideration the use of M quantization levels in the range of min and max amplitude values of each frequency. To test the information map we acquired an undersampled phantom image in which the phase encoding were placed with a density proportional to the information content of the frequencies.

Results

Figure 1 shows the resulting k-space information map obtained form the 500 brain images. This map was calculated with M = 64. The shape of the information map is similar to a Gaussian bell, except in the center of k-space where there is a peak of entropy. Figure 2 and 3 show a phantom image acquired with a 2DFT trajectory. Figure 2 is a normal image with 256 shots and Figure 3 is acquired with the special trajectory with 200 shots and reconstructed to a 256x256 image with gridding.

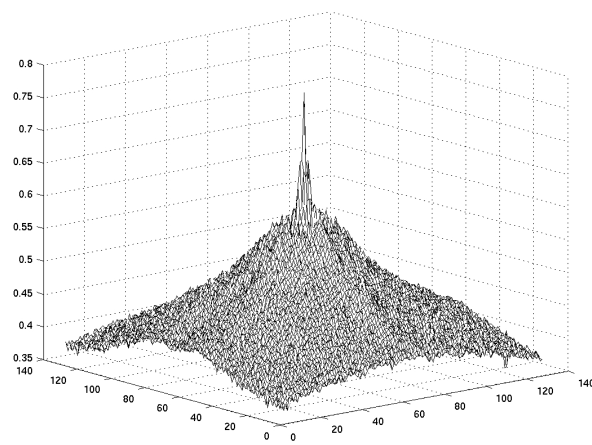

Figure 1: k-space information map obtained from 500 brain images

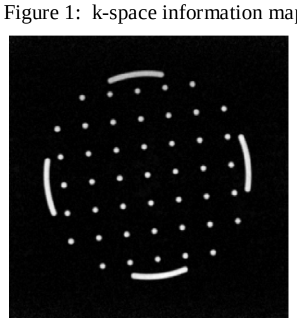

Figure 2: image acquired with 256 shots, 2DFT normal trajectory

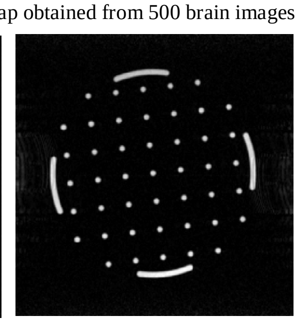

Figure 3: image acquired with 200 shots, 2DFT modified trajectory based on information map

Conclusions

We have validated the general assumption that the outer regions of k-space have less quantity of information that the center, at least for this particular set of scans. The information map obtained, however shows that the entropy doesn't have circular symmetry, existing noticeable directions where the concentration of information is non continuous with the Gaussian shape. When using fast acquisition or undersampled schemes the map can be used as a design tool for undersampling or non-uniform sampling. Finally, several experiments and studies should be made to validate this model for other parts of the body.

Bibliography

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