Compressed Sensing in MRI

Compressed sensing (CS) is a new method of accelerating image acquisition that is based upon the concepts used in image compression. We are all familiar with the concept of compressing images or movies to reduce the space required for storage. The Joint Photographic Experts Group (JPEG) standard is a typical example of a compressed image format that is extensively used to reduce the size of image files, whilst the Motion Picture Encoding Group (MPEG) standard is used to compress video. Both can be performed with little or no reduction in image information.

CS essentially involves this process in reverse. We sample a reduced number of raw MRI data points (*k*-space) and then iteratively reconstruct the image by estimating the missing data points. There are however several requirements for CS to work in the context of MRI. Firstly, the data must be sparse, or be transformed into a sparse representation. Sparsity in this context means that the data contains very little information. An MR angiogram is a good example of sparse data in the image domain. Alternatively, other images may require some form of transformation to make them sparse, for example, the voxels in a standard brain image are relatively smoothly changing with position, i.e., two adjacent voxels are likely to be very similar, so a suitable sparsifying transform could be to simply take the difference between adjacent voxels. More sophisticated algorithms may use a wavelet transformation. Secondly, the aliasing artefacts caused by the sub-sampling of *k*-space must be incoherent (noise-like). We know that regular sub-sampling of *k*-space results in regular aliasing artefacts, whereas if we randomly sample *k*-space then the resulting incoherent artefacts appear much more like background "noise". Finally, an iterative reconstruction algorithm is used that effectively “denoises” that image by retaining the sparsity of the image and the consistency of the reconstruction with the acquired samples. CS can be combined with parallel imaging; however careful choices need to be made in terms of the random sampling distribution. There are several algorithms in the literature that fulfil this requirement as well as commercial implementations being developed by the MRI system vendors.

Figure 1 shows a sagittal image from a 3D acquisition where *k*-space has been under-sampled by 50%, 30% and 24%. The column on the left shows the under-sampled *k*-space in the slice-encoding (k_z) and phase encoding (k_y) directions. Note that the centre of *k*-space is fully sampled. The middle column shows the reconstructed images obtained using a CS reconstruction algorithm. The column on the left shows what happens when the missing data is filled with zeros, note the incoherent noise-like artefacts and the blurring of the images.

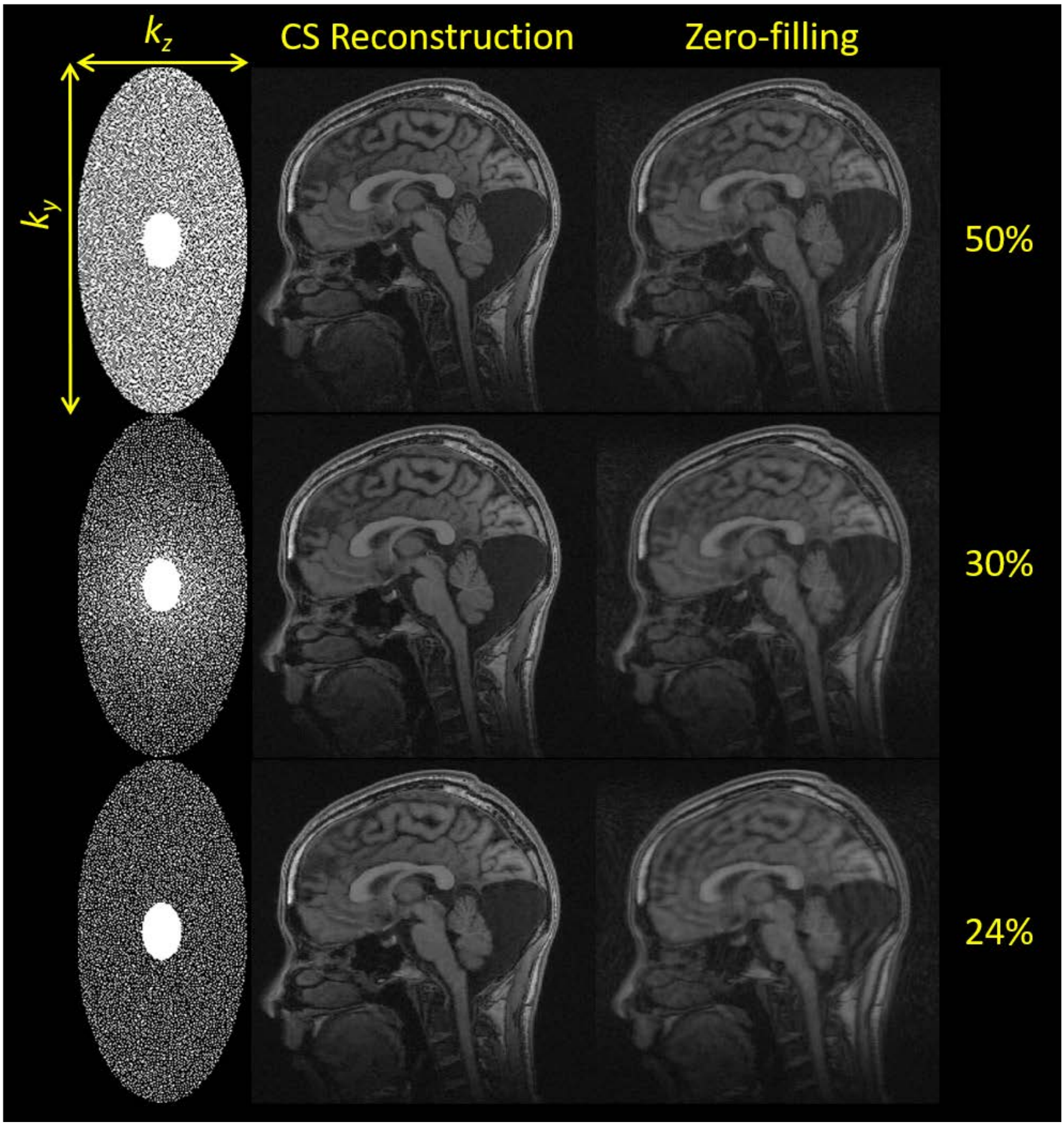

Figure 1 Under-sampled MRI k-space (left) where the missing data is reconstructed using a compressed sensing algorithm (middle) compared to simple zero-filling (right)

References

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