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Fibre-Bundle-Basis Compressive Sensing for *In-vivo* Endoscopy

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For deep brain fluorescence imaging it is necessary to use a thin probe to minimise hemorrhaging and tissue damage. Recently developed methods have used a section of multimode fibre with a known transmission matrix to raster scan a point at the distal end of the fibre for microscopy purposes [1,2]. Although these implants are small, and can offer high resolution, they do not allow for freely moving animals as the transmission matrix is dependent on the fibre shape [2]. They also suffer from a temporal resolution limited to, at best, a few hertz due to their scanning nature. Other methods involve mounting epifluorescence microscopes onto the skulls of mice with implanted graded index (GRIN) lenses [3]. Mounted microscopes, however, tend to impede mouse activity and do not allow for direct optical interaction with the brain as would be required in the case of optical neural stimulation. Fibre bundles can offer fast imaging but greatly reduce spatial resolution. We propose a method by which we can use a fibre bundle with compressive sensing to up sample our recorded images.

To enable up sampling of a low resolution image we exploit known sparsity properties of our expected image. Natural images, as is the case in the example shown in Figure 1, often have few large coefficients in their discrete cosine transform (DCT) and can be considered sparse or pseudo-sparse in this domain. This assumption allows the reconstruction of a higher resolution image. We verified this theoretically by using a segmentation algorithm to generate an intensity transfer matrix from an image of the end face of a 160 μm diameter fibre bundle. We used this matrix to convert a 15,625 pixel image into 1,459 core intensity values before reconstructing the image. We did this by multiplying our fibre matrix by the inverse DCT matrix and finding the solution vector with a minimum l1-norm which satisfies our new under determined linear system of equations.

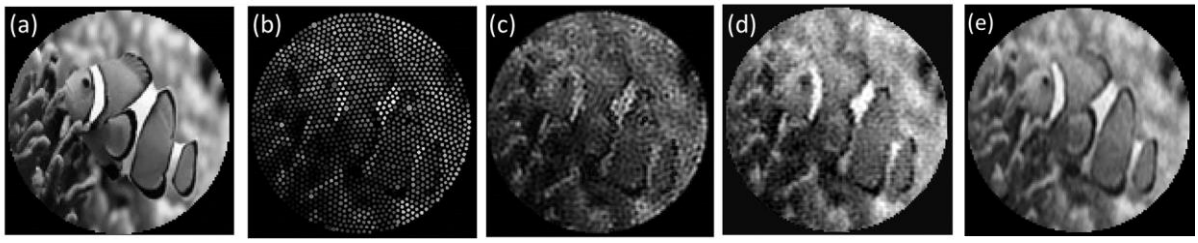

Figure 1: Compressive sensing demonstrated through a fibre bundle. (a) Original image. (b) Image as seen through bundle. (c) Reconstruction by back projection and filtering (RSE = 25.7). (d) Reconstruction by compressive sensing (RSE = 9.77). (e) Best possible reconstruction from 1459 measurements in the DCT basis (RSE = 9.15).

We attempted reconstruction of the original image shown in Figure 1a from the fibre image, Figure 1b. The image shown in Figure 1c is the best that could be achieved by simple back projection through the fibre and Fourier domain filtering. Figure 1d shows the compressive sensing reconstruction whereas Figure 1e shows the reconstruction after choosing the 1459 most significant DCT coefficients giving some idea of a performance limit of this method when using the DCT. These standard errors are comparable indicating that the reconstruction method is viable for imaging. Furthermore, with the right choice of basis, compressive sensing could allow for the regeneration of the high spatial frequencies lost in the fibre bundle. This is not possible with back projection. Presently we are in the processes of testing this method on samples with measured fibre intensity transfer matrices.

References:

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