GPU enabled software toolbox for sparse approximation and matrix completion, by Jared Tanner

The Edinburgh Compressed Sensing Group is developing a long term collaboration with SELEX Galileo, a defence contractor with research and manufacturing facilities in Edinburgh as well as outside the UK. This collaboration is for the testing and evaluation of compressed sensing and matrix completion techniques for imaging modalities. To achieve maximum impact, the collaboration with SELEX Galileo must involve: development of application specific theory, construction of prototype hardware, and writing software capable of implementing the techniques on real world large scale data-sets. The first two of these are tasks are underway with SELEX Galileo co-funding a CASE studentship (Ben Leslie) supervised by Prof. Tanner and hardware commissioned with Prof. Harvey of Heriot-Watt University. Support for the software development was submitted to the EPSRC as part of a special call for HPC software development and for co-funding of a project partner by the US National Science Foundation. The EPSRC proposal received review scores of 6, 6, 6, and 1 (whose complaint was that it was focused on software), but was not funded. The NSF co-funding was successful, supporting Prof. Blanchard's (former Edinburgh postdoc) component.

Although the full EPSRC proposal if far beyond the scope of a maximaths proposals, an important subsection is possible and would fill an essential void in developing a long term collaboration between SELEX Galileo and the Edinburgh Compressed Sensing Group. The full EPSRC proposal is attached for completeness, along with a letter of support from SELEX Galileo.

This proposal considers the fusion of two timely research topics: Graphical Processing Units (GPUs) for computational science and algorithms for compressed sensing and matrix completion. Compressed sensing and matrix completion move compression from postprocessing after data is acquired to being fully incorporated directly in the data acquisition process. The wide ranging applicability of this new technique and interest by defence and industry has rapidly created a large research community in compressed sensing and matrix completion. An important characteristic of compressed sensing and matrix completion is the asymmetric work load being reversed, with the usual detailed sampling and processing with fast transforms replaced with simplified sampling and an increased algorithmic cost of recovering the desired signal from the measurements. Unfortunately, most algorithms found to perform well in practice also have a significant computational burden, this restrictions testing to small problems which limits the ability to accurately catalogue the empirically observed behaviour of algorithms. In particular, the greatest interest involves matrices with few rows compared to columns–where the greatest sampling savings are achieved–but also mandate large matrices.

We propose writing a matlab toolbox of iterative sparse approximation algorithms, witten in CUDA to exploit the extraordinary computational power of programmable GPUs. With the resources requested we will complete implementations of the following algorithms, matrix options, and input options.

1. **Algorithms:** Normalised Iterative Hard Thresholding, Hard Thresholding Pursuit, and Compressed Sensing Matching Pursuit. The basic subroutines needed for these algorithms have already been written, including: fast order statistics, matrix vector products, and the iterative linear algebra algorithms steepest descent and conjugate gradient.

2. **Matrix ensembles:** Fast discrete cosine transforms, sparse matrices, and general dense matrices. Options will be given for these ensembles to be automatically generated for east of algorithm testing, and for input from matlab of matrices of these forms.

3. **Testing environment for synthetic and model applications.** Routines for the testing the algorithms on synthetic testing problems for the single pixel camera under development by SELEX Galileo.