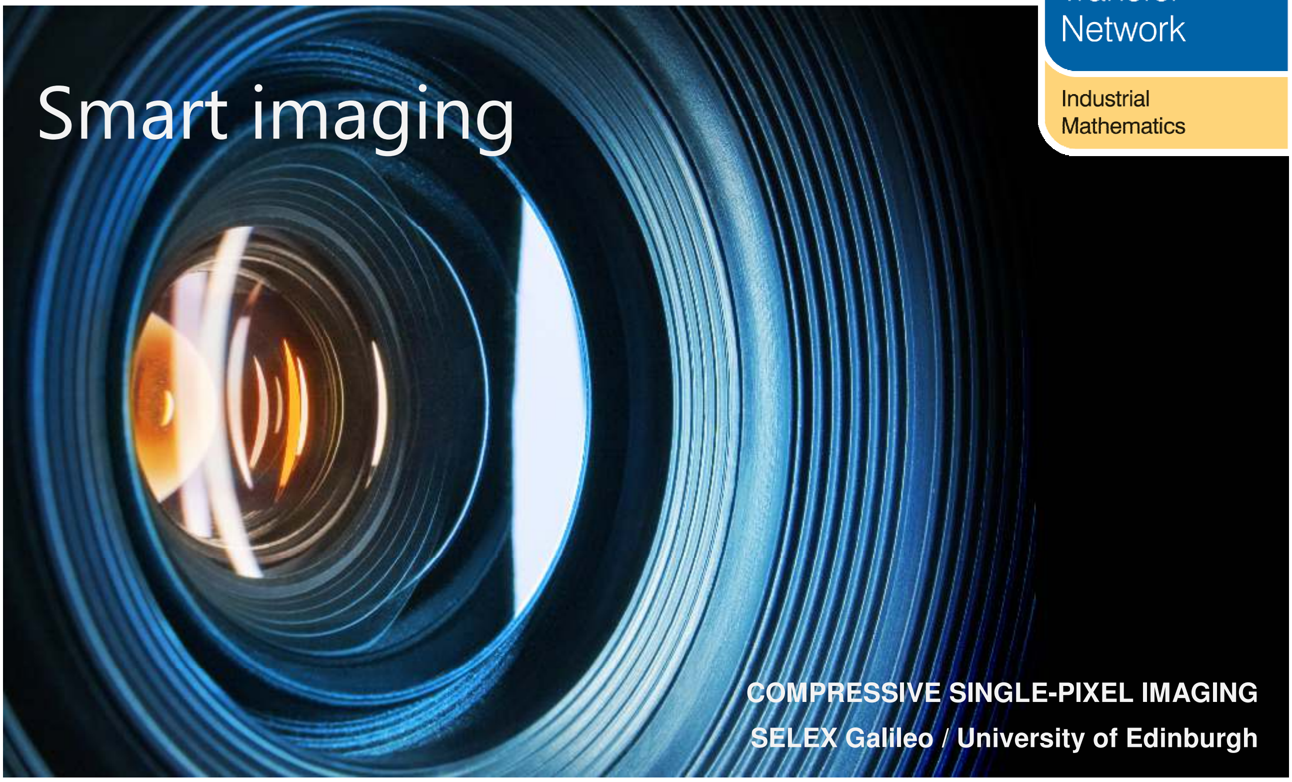

Smart imaging

COMPRESSIVE SINGLE-PIXEL IMAGING

SELEX Galileo / University of Edinburgh

The need

For imaging in the visible spectrum, CCD and CMOS technology has allowed effective and compact airborne sensing devices to be developed for the defence industry. These devices typically acquire pixel samples by means of a full array of photon detectors.

For imaging in other wavelengths, more exotic detectors may be required, but a vast array of these expensive and bulky detectors may no longer be feasible, and would create problems of computation and storage.

Compressed Sensing (CS) offers a potential solution to all these issues. The project looked to build and test a mathematical model of the camera design suitable for CS.

The outcomes

The remit of the project was to build and test a mathematical model of the camera design using MATLAB. In particular, this required appropriate Compressed Sensing (CS) reconstruction algorithms to be developed and studied.

The focus was at first on 2D imaging, with the second part of the project addressing how the 2D imaging techniques can be extended to 3D imaging.

Having built the model, suitable performance metrics were identified, and subsequently used to evaluate the effectiveness of the model when applied to real and synthetic data.

SELEX Galileo were provided with a working model, and with insight into where such a technology would be likely to find an application.

Figure 1 shows an example where the model reconstructed an image using only 15% of the original image.

Figure 1: LWIR image of a simulated scene (left), along with the image reconstructed using the algorithm (right)

> *"Andrew has applied successfully his CS theoretical knowledge to the challenge of designing both 2D and 3D compressive imaging algorithms. The results of this work have provided valuable insight into the capabilities of CS technology…"*
>
> **David Humphreys**
> **SELEX Galileo**

Technical summary

A team at Rice University have proposed a novel camera model which fits directly into the CS paradigm [1]. Instead of taking pixel samples, a randomized sum of the incident light is directed, by means of a Digital Micromirror Device (DMD), onto a single-element detector. A series of consecutive samples can be acquired in this way.

The sampling process was modelled as a series of noisy linear randomized measurements, which gives a clearly defined problem to be solved by the reconstruction algorithm.

Three CS reconstruction algorithms were selected from those proposed in the literature for the 2D problem:

- l_1-projection (based on SPGL1)
- Normalized Iterative Hard Thresholding
- Iterative Tree Thresholding.

While being competitive in terms of recovery properties, they are also among the fastest CS algorithms available.

Both the sampling and reconstruction models were extended to the case of 3D dynamic images (video sequences), which is a natural extension to the 2D case, and has already been considered in the literature [2].

A wide range of numerical experiments were carried out, using performance metrics such as mean-squared error as a measure of reconstruction accuracy, peak signal-to-noise ratio as a measure of contrast, and also algorithm running time.

Industry standard test images and images simulated by CAMEOSIM were used to systematically explore how the performance metrics are impacted by the level of undersampling and algorithm parameters. More specific experiments were also conducted, which explored

- robustness to noise
- multi-spectral imaging
- imaging of cluttered scenes
- remote imaging
- extension to moving images (3D)

[1] Duarte, M. et al. *Single-pixel imaging via Compressive Sampling* , IEEE Signal Processing Magazine, Vol. 25(2), pp 83-91 (2008).

[2] Wakin, M. et al. Compressive Imaging for Video Representation and Coding, Proceedings of the Picture Coding Symposium, Beijing, China (April 2006).

"I have gained insight into the practical issues surrounding the use of these algorithms in an industrial setting, and this insight will help to inform my PhD studies in the future. The project has also enabled me to develop my image processing and programming skills."

Andrew Thompson, University of Edinburgh

"[The project's] 'hands-on' experience has had an invaluable formative role in Andrew's studies, illustrating the challenges of practical real-life problems and how these can lead to modifications and even improvements to existing algorithms."

Coralia Cartis
University of Edinburgh

Project Details

Partners

SELEX Galileo
University of Edinburgh

Project investment

£13,000

Intern

Andrew Thompson

For details on the technology:
David Humphreys
SELEX Galileo
david.humphreys@selex-galileo.com

For information on internships and other collaborations:
Lorcán Mac Manus
Industrial Mathematics KTN
lbmm@industrialmaths.net
+44 (0) 1483 579108

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