IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

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| **Project Title:** | **Steal Functions: Creating Digital Objects With Low Visibility** | |
| **Project Number** | **IMURA0389** | |
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## Research Academy Themes:

**Highlight which of the Academy's Theme(s) this project will address?**
***(****Feel free to nominate more than one. For more information, see www.iitbmonash.org)*

1. Advanced computational engineering, simulation and manufacture
2. Infrastructure Engineering
3. Clean Energy
4. Water
5. Nanotechnology
6. Biotechnology and Stem Cell Research

## The research problem

*Define the problem*

Ghosts are digital images comprised of positive and negative valued pixels arranged as to sum to zero and vanish when projected at one or more digital angles. These ghosts have strong links to the artefacts that are created when real images are reconstructed from projected views, as done in conventional x-ray CT.

These ghosts originate from a result obtained long ago by Katz [1] that determines if any digital object can be reconstructed exactly from any set M of projected views. The properties of ghosts are thus of quite general importance in deciding if any set of projection data can be reconstructed exactly or not. In an odd twist, it turns out the ghosts can be used for the exact recovery of lost projection data, providing there is some redundancy in the image data [2].

Ghost functions exhibit very strong symmetries and remarkable survival properties; they can be subjected to a variety of affine transforms, including discrete rotations [3], to

produce a large family of ghosts which are close to orthogonal but persistently vanish at a pre-determined number of projection angles [4-7].

One aim of this work is to use these low-visibility shapes as a sensitive probe to test the efficacy of different image reconstruction approaches [8]. The “complexity” of the ghosts from the point of view of reconstruction, will need to be investigated. Another aim is to exploit their strong “near-perfect” auto-correlation properties to embed hidden data or water-marks in documents for image labelling or security applications [9]. In both these applications, the advantages or special merits of using ghosts will be investigated, so as to compare the performance with other existing methods in the literature.

**References**


[1] Questions of uniqueness and resolution in reconstruction from projections, Katz, M., Springer Verlag, 1977.

[2] An exact, non-iterative Mojette inversion technique utilising ghosts, Shekhar Chandra, I. Svalbe and Jeanpierre Guédon, Discrete Geometry for Computer Imagery, Lyon, April, 2008, Springer, LNCS volume 4992, pp. 401-412.

[3] Exact, scaled image rotations in finite Radon transform space, Imants Svalbe,

Pattern Recognition Letters, online http://doi:10.1016/j.patrec.2010.06.015

[4] Recovering missing slices of the discrete Fourier transform using ghosts, S. Chandra, I. Svalbe, JP. Guédon, A. Kingston and N. Normand, IEEE Transactions on Image Processing, vol. 21, no. 10, 4431-4441, 2012.

[5] On constructing minimal ghosts, Svalbe, I., Normand, N., Nazareth N., Chandra, S., APRS Conference, DICTA 2010, Sydney, Australia, 1-3 December, http://dx.doi.org/10.1109/DICTA.2010.56.

[6] Properties of minimal ghosts, Svalbe, I., Normand, N., Debled-Renesson et al. (Eds.): DGCI 2011, LNCS 6607, 417-428, http://dx.doi.org/10.1007/978-3-642-19867-0_35.

[7] Growth of discrete projection ghosts created by iteration, Svalbe I., Chandra, S., Debled-Renesson et al. (Eds.): DGCI 2011, LNCS 6607, 406-416, http://dx.doi.org/10.1007/978-3-642-19867-0_34.

[8] Image reconstruction from a small number of projections, Herman, G.T., Davidi, R., Inverse Problems 24 (2008) 045511, (17 pp.).

[9] Near-perfect correlation functions based on zero-sum digital projections, Svalbe, I. APRS Conference DICTA 2011, December 6-8 2011, Noosa Heads, Queensland, Australia


## Project aims

*Define the aims of the project*

To construct 2D digital images that have zero or near-to-zero sums when the object intensities are projected at a wide range of viewing angles. These shapes could be extended to 3D and higher.

To apply these digital shapes as one or more of the following; fidelity tests for 2D image reconstruction algorithms, as digital oriented filters, for embedding in images as near-perfect auto-correlation functions as fiducial markers or as watermarks for image security.

## Expected outcomes

*Highlight the expected outcomes of the project*

Capacity to generate a wide selection of ghost shapes that exhibit perfect invisibility over a pre-defined range of view angles, initially in 2D data.

Quantitative measure of the sensitivity and robustness of these ghosts when applied as orientation sensitive filters or when used as correlation functions to extract weak signals embedded in image data.

## How will the project address the Goals of the above Themes?

*Describe how the project will address the goals of one or more of the 6 Themes listed above.*

The project uses state of the art image reconstruction ideas that are germane to digital data storage, encryption and transmission protocols, as well as applications in medical and industrial tomography.

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## Capabilities and Degrees Required

*List the ideal set of capabilities that a student should have for this project. Feel free to be as specific or as general as you like. These capabilities will be input into the online application form and students who opt for this project will be required to show that they can demonstrate these capabilities.*

Ability to produce scripts for programs such as Matlab or subroutines written in C/C++. Familiarity with basic signal and image processing ideas, filtering and image reconstruction capability will be advantageous. Ability and willingness to work on problems that involve computational mathematics or signal processing.