Simultaneous x-ray transmission CT and fluorescence imaging

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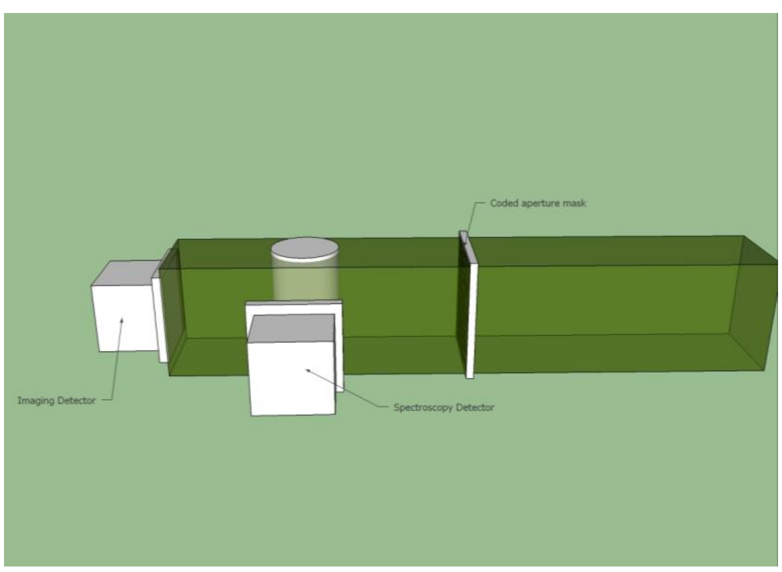
Introduction

X-ray imaging exploits differences in the complex x-ray refractive index of materials to obtain spatial information on electron density. This technique has been used for over 100 years and is a popular in many areas of research. The use of x-ray fluorescence from an object for imaging has taken a little longer to emerge, but is now a mainstream imaging technique for materials analysis, especially on synchrotron storage ring sources. We propose that if these two techniques are combined and information obtained simultaneously on electron density and elemental concentration, It would add greatly to the characterisation of the object.

The Idea/Concept

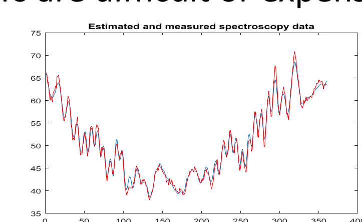
We have been exploring methods of using coded illuminating beams during x-ray computed tomography to obtain estimated fluorescence maps of the object. This is done in such a way that has little effect on the quality of the x-ray CT, but the fluorescence emission from regions within the object are sufficiently encoded. To this end we are currently trialling a manifestation of compressed sensing on the Imaging and Medical Beamline (IMBL) at the Australian Synchrotron. Initial experiments have been performed with some encouraging results. The technology we are investigating may be applied to other situations especially where highly segmented detectors are difficult or expensive to develop.



2D results

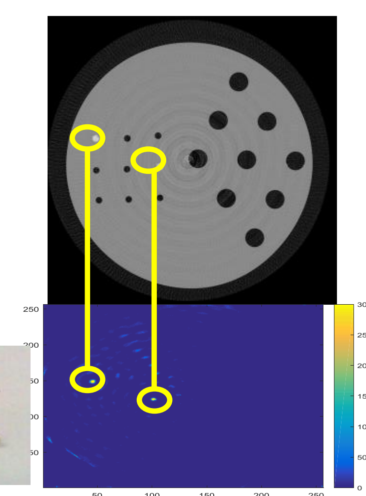
Experiments using a very simple 1-D beam encoding mask and a single point spectroscopy detector have already shown promise[1]. Data was recorded from a spectroscopy detector collecting x-ray fluorescence photons from an object during a 180 degree x-ray CT scan.

We have subsequently successfully reconstructed a single slice fluorescence map of iodine solution in a plastic (PMMA) phantom.



Spectroscopy detector output

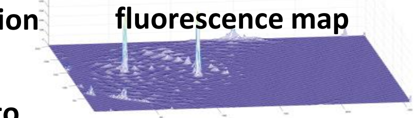
CT slice



Plastic phantom
Different diameter bores are used to contain the fluorescing material.

Comb mask for beam modulation

Reconstructed fluorescence map



Reconstruction

Our first experiments used a fixed period comb mask to modulate the beam. The reconstruction was achieved using a modelled system matrix and a MLEM procedure. We are in the process of fabricating a variable, random mask with which we can use compressive sensing techniques for the reconstruction. The random pattern of ray sum fluorescence stimulation, along with the rotation during measurement, has been shown in models to provide a suitable measurement matrix. The many types of sparse $\ell 1$ norm minimising algorithms can be trialled.

Potential Impact

Combining FXCT with 'standard' CT provides useful extra information about the object. The CT image gives 3D distribution of x-ray attenuation (or more broadly refractive index). The FXCT provides a 3D estimate of the distribution of elemental concentration. Elemental markers may be a natural part of the object (endogenous) or introduce in order to mark a particular feature (exogenous). For biomedical imaging exogenously marked features could highlight processes in the living systems, thereby providing functional imaging. This would be similar information to that obtained by other emission topographies, which use radioactive elements as markers. In the case of the FXCT the emission is stimulated by the incident beam, removing the need for radioactive markers.

References: (1) C. Hall et al 2016, Journal of Instrumentation, 11, C03048

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