Fusion of magnetic induction tomography with X-ray CT for detection and classification of concealed threats and fine defects

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This project will combine Magnetic induction tomography (MIT), a novel nonlinear imaging technique, with X-ray projections in a limited set of views to develop a methodology for security screening of cargo containers. MIT allows reconstruction of conductivity which is an important material parameter when looking for threats, whereas the addition of X-Rays allows a separate material parameter to be assessed as well as improving image resolution.

The research will combine numerical modelling of PDEs for electro-magnetic radiation with inverse problem techniques based on nonlinear optimisation, construction of priors for joint estimation of parameters exploiting cross-information of structure, and machine learning.

In nonlinear PDE based inverse problems such as MIT, each step of the iterative reconstruction requires running multiple forward solvers. It is therefore paramount to accelerate these e.g. using efficient preconditioners. We will look into exploiting the prior information in constructing preconditioners for the chosen forward solver through for instance training neural operators which are then fine tuned on a small set sampled from the prior.

Use of AI methods is challenging for large scale inverse problems because of the lack of suitably large training sets, hence the project will focus on unsupervised learning and generative models. The combination of these between different modalities and the inherent non-linearity of the forward models will afford many novel areas of research.

Further avenues to explore to improve the reconstruction problems are for instance joint reconstruction and classification (predicated on availability of data on which we could train the classifier) or incorporation of uncertainty quantification into the reconstruction. The latter is very challenging due to the non-convexity of the data fidelity.

At UCL the supervision team will between professors Simon Arridge and Marta Betcke in Computer Science and Timon Betcke in Mathematics. They have extensive experience in tomography and image reconstruction for modalities such as X-Ray CT, Magenetic Resonance Imaging, Positron Emission Tomography, Ultrasound and Optical Imaging. They are part of the UCL Centre for Inverse Problems which enables cross disciplinary research between Mathematics, Physics, Engineering and Computer Science. The project will be in collaboration with AtomicWeapons Establishment (AWE) who will provide experimental data of test phantoms with known properties for validation of the developed methods.#

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[3] Ehrhardt, M. J., and Betcke, M. M., 2016, Multi-contrast MRI reconstruction with structure-guided total variation. SIAM Journal on Imaging Sciences. 9, 3, p. 1084-1106