Engineering Science for Health CDT – Project Descriptions

Sensors and Imaging Research Theme

The Engineering Science for Health (ESH) CDT explores research in engineering, mathematics and the physical sciences with applications to Healthcare technologies. The CDT is highly multidisciplinary and includes PGR students with backgrounds in Chemistry, Physics, Biosciences, Engineering, Computer Science and Mathematics. Our research is divided into 4 main research themes which are all focussed on Healthcare applications:

(1) Sensors and Imaging

(2) Biological and Molecular Systems

(3) Computational Methods and Modelling

(4) Patient Focussed Technologies.

A range of PhD research projects will be offered across all 4 themes, with students supported by a multi-disciplinary supervisory team.

This document gives more information about the projects offered within the Sensors and Imaging research theme.

Summary of Projects - Sensors and Imaging Research Theme

Ref Num:	Project Name	Primary suitability for applicants from these disciplines:					
		Physics	Chemistry	Bioscience	Maths	Computing	Engineering
4.1	In-line extraction of spectral features from hyperspectral X-ray and gamma images	**X**			**X**	**X**	**X**
4.2	Novel approaches to scatter correction, reconstruction and dosimetry in therapeutic nuclear medicine	**X**			**X**	**X**	**X**
4.3	Perovskite high sensitivity X-ray and gamma detectors for medical imaging	**X**	**X**				**X**
4.4	The Chemistry of High Efficiency Perovskite Nanoparticle X-ray Detectors	**X**	**X**				**X**
4.5	Development of a genetic algorithm optimised fuzzy logic scintillator selection tool for medical physics	**X**			**X**	**X**	**X**

For general information about any of the ESH projects, or the application process, please contact eshcdt@surrey.ac.uk

Research Theme Overview

The increasing demand for low-cost, precise, and accurate radiology analysis enabling early diagnosis and classification of disorders, alongside the sustained shortage of radiologists, is driving the demand for development and deployment of complex analysis solutions In this research theme we will develop and apply machine learning methods for clinically-focussed health and medical technologies. High-quality and independent datasets will be used to clinically validate analysis methods for healthcare, along with robust validation procedures and reliable assessment frameworks. The research theme will also develop new sensor and measurement technologies, such as high sensitivity X-ray sensors and spectroscopic imaging systems, which will be applied to medical imaging applications.

Project Descriptions:

Ref Number:	4.1	**Project Title:**	In-line extraction of spectral features from hyperspectral X-ray and gamma images
		Project Supervisor(s):	Silvia Pani

Project Description: Improvements in X-ray and gamma ray detector technology have allowed significant improvements in quantitative imaging in terms of accuracy and/or patient dose reduction.

This project, carried out in collaboration with the Detector Development Group at STFC Rutherford Appleton Laboratory, will specifically focus on pixellated spectroscopic detectors. Such devices output the full spectrum of radiation detected by each pixel, thus providing a significantly larger amount of information compared to conventional detectors with a single exposure.
Quantitative imaging is performed by combining the information corresponding to different spectral components. In X-ray imaging it may be applied, for instance, to tissue characterisation.

This project will look at novel approaches for quantitative imaging based on AI, looking in particular at the extraction of relevant spectral features for each application, with the possibility of in-line optimisation of the acquisition parameters.

Ref Number:	4.2	**Project Title:**	Novel approaches to scatter correction, reconstruction and dosimetry in nuclear medicine theragnostics
		Project Supervisor(s):	James Scuffham

Project Description: Molecular Radiotherapy involves the use of radioactive drugs (radiopharmaceuticals) to treat cancer. This is usually achieved by labelling a molecule that binds biochemically to cancer cells with a radioactive element that emits beta or alpha particles. The radiation then causes DNA damage within the cancer cell, which results in cell death. As with all radiotherapy, there is a balance to be struck between damaging cancer cells and normal tissues. The concept of theragnostics essentially involves substituting the radioactive element of the radiopharmaceutical with one that emits gamma or positron radiation, allowing high-quality diagnostic imaging of the drug distribution prior to therapy. This should allow accurate planning of the radiation dose delivered to target and non-target organs. However, there are technical challenges associated with accurately converting these images into measurements the radioactivity concentration as a function of time, which is needed for accurate dosimetry. This project seeks to address some of these challenges.

The project will investigate the use of the full spectral data from novel detectors and state-of-the-art clinical gamma cameras, to improve quantitative accuracy in tomographic image reconstruction. In particular, novel approaches to correcting for Compton-scattered photons (which degrade accuracy) will be explored, and the impact of these on subsequent dosimetry calculations assessed. The project will involve a mix of experimental work with “phantoms” (test objects containing known quantities and distributions of radioactivity) and computational work with simulations (to generate “ground-truth” data) and advanced reconstruction algorithms.

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Ref Number:	4.3	Project Title:	Perovskite high sensitivity X-ray and gamma detectors for medical imaging
		Project Supervisor(s):	Paul Sellin p.sellin@surrey.ac.uk

Project Description:

New technologies for digital X-ray sensors are currently revolutionising many aspects of public health and security, from medical imaging systems to the latest "3D" X-ray scanning technology used in airports. In this research project you will develop perovskite-based radiation detectors for use in X-ray and gamma imaging detectors for security applications. The security market uses imaging detectors for portal scanners, eg to interrogate persons or vehicles in the search for illicit nuclear materials. Perovskite scintillators are high-Z materials which unique radioluminescence properties, which offer energy discrimination and improved sensitivity for X-ray and gamma rays compared to traditional plastic scintillators.

The team at Surrey has recently demonstrated the performance of new perovskite materials which have excellent properties for use as radiation detectors for X-ray and gamma ray sensing. These materials have a unique set of optical and electrical properties, including good electronic charge transport, high radioluminescence light yield, high material density, good optical transparency due to a high Stoke's shift, and a fast response time. In this project you will develop prototype perovskite detectors fabricated from perovskite materials synthesised in the group. The research will characterise the fundamental electrical and optical properties of these new materials and demonstrate their performance in prototype X-ray and gamma ray imaging detectors. The project may focus either on perovskite materials as scintillation detectors, or using their electronic properties as direct detectors.

The research project will combine the study of the perovskite materials with the development of prototype radiation imaging detectors to demonstrate the performance of these materials as real imaging devices. Using the group's X-ray facilities and optical imaging cameras, the spatial resolution and imaging quality of the materials will be measured. This multi-disciplinary research project will benefit from the excellent material characterisation facilities in the Chemistry and Materials Science departments, for example using Photoluminescence, Raman, Dynamic Light Scattering, SEM/TEM and XRD.

This project is ideal for a Physics graduate with an enthusiasm for experimental research, with either a Batchelors or Masters degree. Students with equivalent backgrounds in chemistry or materials science will also be considered.

For background information on this project, please see this OpenAccess review paper: "Recent Progress in Single-Crystalline Perovskite Research Including Crystal Preparation, Property Evaluation, and Applications", https://doi.org/10.1002/advs.201700471

The project supervisors are Prof Paul Sellin https://www.surrey.ac.uk/people/paul-sellin and Dr Carol Crean https://www.surrey.ac.uk/people/carol-crean

Ref Number:	4.4	Project Title:	The Chemistry of High Efficiency Perovskite Nanoparticle X-ray Detectors
		Project Supervisor(s):	Carol Crean https://www.surrey.ac.uk/people/carol-crean

Project Description:

In this project we target crystalline double perovskite materials, which offer a uniquely high light yield from X-rays, compared to traditional scintillating materials. Double perovskites with the general formula A2B'B''X6 are an attractive alternative to lead halide perovskites since they have good stability and excellent optoelectronic properties. These materials exhibit strong X-ray absorption and intense radioluminescence at visible wavelengths and can generate X-ray induced optical emission that is easily tuneable across the visible spectrum by varying the material stoichiometry.

In this proposal we focus research on the underpinning materials chemistry of crystalline double perovskites. The focus of the research will be to develop new synthesis and processing methods for crystalline double perovskite for use as scintillation-based radiation detectors, with the following key objectives:

- Synthesis of alternative lead-free double perovskite materials. This will address future commercial requirements for lead-free sensor technologies.
- Improved synthesis methods, to increase synthesis yield and to improve material quality.
- Tuning the double perovskite composition to vary the optical emission across the spectrum.
- Studies of crystalline material stability, and the effect of appropriate surface treatments, both chemical and mechanical.

For background information on this project, please see this OpenAccess review paper: "Recent Progress in Single-Crystalline Perovskite Research Including Crystal Preparation, Property Evaluation, and Applications", https://doi.org/10.1002/advs.201700471

The project supervisors are Dr Carol Crean https://www.surrey.ac.uk/people/carol-crean and Prof Paul Sellin https://www.surrey.ac.uk/people/paul-sellin

Ref Number:	4.5	Project Title:	Development of a genetic algorithm optimised fuzzy logic scintillator selection tool for medical physics
		Project Supervisor(s):	Caroline Shenton-Taylor https://www.surrey.ac.uk/people/caroline-shenton-taylor

Project Description:

Scintillators facilitate the conversion of absorbed radiation into light making them a desirable material for medical physics applications. From position emission tomography (PET), single-photon emission computerized tomography (SPECT), mammography – scintillators provide the timing and position of gamma event conversion within the detector. New multi-modal imagining systems require optimised scintillator performance across an extended energy range, and may include use of transparent ceramic materials. This project seeks to create a fuzzy logic tool to facilitate rapid scintillator material section aligned to the intended medical application. Fuzzy logic is an established mathematical technique allowing variables belonging to multiple states to be combined. It is a many-valued logic approach; input variables can take a range of values between 0-1 but are combined in such a way to give a single numeric output. The technique is used in many fields e.g. to help control car braking systems and washing machine settings. This project will apply fuzzy logic to quantify the performance of scintillator materials for radiation detection within medical physics. The approach taken will combine multiple input parameters, both those described quantitatively and qualitatively, within a fuzzy logic tool. Parameters will include: scintillator density, melting point, thermal expansion, hardness, emission wavelength, decay time, light yield, reliability, robustness and cost. The importance weighting of each parameter will be assigned through genetic algorithm optimisation, with project consideration given to an appropriate fitness function. In the first instance, a graphical trapezoidal method with simple fuzzy logic rules will be applied to combine and then defuzzify the inputs to score scintillator performance per identified medical application. Other fuzzy combination approaches will also be explored within the research. The project outputs include: a comprehensive database of current and emerging scintillator materials, scintillator parameter importance assigned through genetic algorithm optimisation, and a comprehensive fuzzy logic tool to facilitate optimised scintillator selection for identified medical applications.

[1] A. Beale, Journal for the International Association of Physics Students (jIAPS) https://cloud.iaps.info/s/FZW87xHtCofxZiY (accessed Nov 2022)

[2] C. Shenton-Taylor, G. Hurst, K. Duroe, P.R. Arthur, 2022 IEEE Nuclear Science Symposium and Medical Imaging Conference Record
https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6551052

(accessed Nov 2022)