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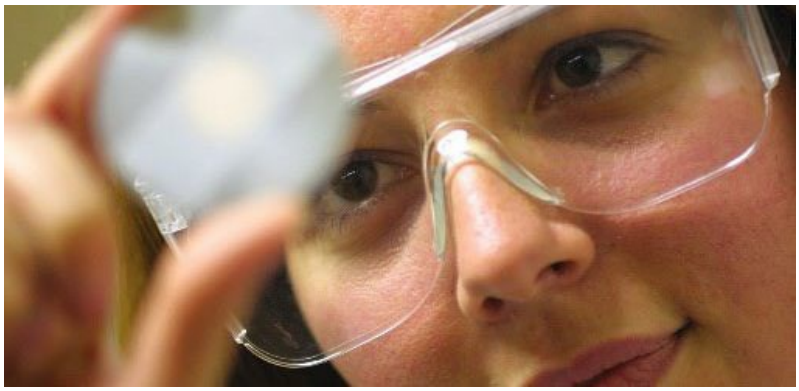
PSIBS Research

Research at the Life Sciences Interface is well established at Birmingham, with many strong and ongoing multidisciplinary collaborations in bio-imaging. PSIBS students are thus involved in a wide variety of interconnected research topics and the Doctoral Training Centre environment and ethos are extremely conducive to multidisciplinary work.



We believe the full potential of technical developments in chemical/physical sciences or engineering/instrumentation can only be realised through the application of innovative and sophisticated mathematical and computational tools capable of extracting and maximum utilisation of information pertinent to biomedical sciences – information which may otherwise lie hidden in 'raw' image data. With this in mind, projects are designed to ensure that on completion each student has expertise in, and has made original contributions to, a life science system, an imaging technology, and the associated mathematical/computational modelling, analysis or processing.

Listed below are examples of some of our internationally leading research in technical areas and the important problems in biosciences and medicine to which we contribute. PSIBS PhD students participate in these and similar research programmes, working with teams of physical scientists, computer scientists and life and medical scientists.

Meanwhile, and coupled to the research programmes, a variety of advances in imaging **instrumentation (/research/activity/psibs/about/facilities-instrumentation.aspx)** are under development: a TIRF endoscope to allow TIRF to be used in the body; a new molecular imaging system for in vivo fluoresence imaging; optical imaging of the brain; a unique fluorescence lifetime microscope for studying lanthanide complexes in cells.

Open all sections

New molecular markers and probes

1. Development of fluorescent molecular probes for the detection of unusual DNA structures (e.g. DNA junctions) and for following pathways and localisations of drugs in cells
2. New molecular probes based on lanthanide fluorescent markers with narrow emission peaks, long decay times, small mass and high stability against photo-bleaching
3. Lanthanide molecular MRI active markers, for imaging specific tumours and macrophages and for tracing the movement and localisation of proteins in cells and tissues
4. Micro-MRI contrast agents utilising oscillations between oxidative states in transition metal ion complexes for probing the chemistry of biosystems
5. Novel computational / analytical components include predictive modelling of the image formation process to optimise the design of imaging systems and imaging protocols, image reconstruction, visualisation, quantification and pattern recognition for abstract dynamic data sequences

New fluorescent, MRI and multi-technique molecular probes are being developed for imaging blood flow, labelling and tracking cells, and visualising and quantifying receptors to guide therapeutic treatment regimes. This work is conducted by:

- **Britton (/staff/profiles/chemistry/britton-melanie.aspx)**, **Hannon (/staff/profiles/chemistry/hannon-michael.aspx)**, **Peacock (/staff/profiles/chemistry/peacock-anna.aspx)**, **Pikramenou (/staff/profiles/chemistry/pikramenou-zoe.aspx)**, **Snaith (/staff/profiles/chemistry/snaith-john.aspx)**: Chemistry
- **Chipman (/staff/profiles/biosciences/chipman-kevin.aspx)**, **Hodges (/staff/profiles/biosciences/hodges-nik.aspx)**: Biosciences
- **Claridge (http://www.cs.bham.ac.uk/~exc/)**: Computer Science
- **Brain (/staff/profiles/cem/neubio/Brain-Keith.aspx)**, **Kysela (/staff/profiles/cem/RGD/kysela-boris.aspx)**, Nash, **Thomas (/staff/profiles/cem/CVRS/Thomas-Steve.aspx)**, **Watson (/staff/profiles/cem/CVRS/Watson-Steve.aspx)**: Medicine
- **Yao (http://www.cs.bham.ac.uk/~xin/)**: CERCIA - Centre of Excellence for Research in Computational Intelligence

Nano-microscopy

1. Combining Liquid Phase Atomic Force Microscopy imaging and near-field optical fluorescence measurements to characterise the morphology and function of quaternary-scale protein complexes for investigating cell signalling and the immune system
2. Fabrication and imaging of gold nano-particles and novel quantum dots for super-resolving microscopy
3. Advancing Scanning Near-field Optical Microscopy for high resolution imaging of fluorescence enhancement and quenching of fluorescent proteins and molecules
4. Developing techniques for multiphoton and nano-manipulation of genomic DNA damage in cells to follow chromatin dynamics

Specialised image analysis algorithms are required for the derivation of morphological and functional information and for 3D visualisation of abstract data and patterns; modelling and analysis are fundamental in the optimisation of properties of the nano-markers (particles and dots). This work is conducted by:

- **Armstrong (/staff/profiles/biosciences/armstrong-sue.aspx)** : Biosciences
- Chen, **Palmer (/staff/profiles/physics/palmer-richard.aspx)** : Physics
- **Preece (/staff/profiles/chemistry/preece-jon.aspx)** : Chemistry

NMR/MRI/micro-MRI

1. Combining MR spectroscopy, in vitro magic angle spinning NMR for mapping tumour tissue and gene expression, and development of advanced computer analysis for the diagnosis, management and understanding of childhood brain and nervous system tumours
2. Development of new regimes for functional brain imaging and subsequent analysis and classification, including joint EEG and fMRI and of new pattern classification systems for data analysis and ultra-high-resolution imaging
3. Development of electron paramagnetic resonance imaging to follow redox reactions in biological systems non-invasively in situ

BUIC (/schools/psychology/facilities/index.aspx) focuses on the use of MRI and related techniques to investigate the brain. MRI is also used to study childhood brain tumours in a clinical setting and is being explored for tracking the movement of cells within the body. This work is conducted by:

- **Bagshaw (/staff/profiles/psychology/bagshaw-andrew.aspx)** , **Humphreys (/staff/profiles/psychology/humphreys-glyn.aspx)** , Kourtzi, **Miall (/staff/profiles/psychology/miall-chris.aspx)** : BUIC
- **Tino (http://www.cs.bham.ac.uk/~pxt/)** : Computer Science
- **Britton (/staff/profiles/chemistry/britton-melanie.aspx)** , Pikramenou: Chemistry
- **Macaskie (/staff/profiles/biosciences/macaskie-lynne.aspx)** , **Viant (/staff/profiles/biosciences/viant-mark.aspx)** : Biosciences
- **Adams (/staff/profiles/iandi/adams-david.aspx)** , **Peet (/staff/profiles/cancer/peet-andrew.aspx)** : Medicine

Image analysis

1. Novel methods based on physics of image formation for the quantitative characterisation of structure and composition of tissues from multispectral images in microvital microscopy
2. Molecular imaging through to whole body optical imaging
3. Probabilistic estimation of FRET for studying protein-protein interactions
4. Optimal wavelength selection for high-speed high-accuracy multispectral imaging of the dynamic behaviour of several proteins simultaneously in living cells using multi-fluorescence microscopy
5. Scatter modelling and analysis for tissue and cellular structure characterisation using polarised and non-polarised diffuse light
6. Computational (Monte Carlo) modelling for the quantitative characterisation of pathological tissues from multispectral images
7. Non-invasive imaging tools for the simultaneous measurement of refractive index and physical thickness using Fourier domain Optical Coherence Tomography

Computational approaches to simplify complex image data and extract key information is combined with modelling of the image acquisition and the interaction of the light with different biological tissues. This work is conducted by:

- **Baker (/staff/profiles/gees/baker-nigel.aspx)** : Geography, Earth and Environmental Sciences
- **Claridge (http://www.cs.bham.ac.uk/~exc/)** , **Dehghani (http://www.cs.bham.ac.uk/~dehghanh/)** , **Rowe (http://www.cs.bham.ac.uk/~jer/)** , **Styles (http://www.cs.bham.ac.uk/~ibs/)** : Computer Science
- **Grover (/staff/profiles/chemical-engineering/grover-liam.aspx)** , **Fryer (/staff/profiles/chemical-engineering/fryer-peter.aspx)** , **Norton (/staff/profiles/chemical-engineering/norton-ian.aspx)** : Engineering
- Nash: Medicine
- **Landini (/staff/profiles/dentistry/landini-gabriel.aspx)** , **Palin (/staff/profiles/dentistry/palin-will.aspx)** , **Walmsley (/staff/profiles/dentistry/walmsley-damien.aspx)** : Dentistry
- **Pikramenou (/staff/profiles/chemistry/pikramenou-zoe.aspx)** : Chemistry

Intelligent data analysis and optimisation

1. Novel techniques for pattern recognition, sequence prediction, high-dimensional data visualisation, classification, data mining and modelling, applicable to the analysis of complex and large image-derived data sets (e.g. evolutionary algorithms for gene expression microarray data analysis, Support Vector Machines for gene selection, evolutionary optimisation for derivation of non-linear, histology basis functions in multispectral image data)
2. New algorithms for non-linear and adaptive optimisation (e.g. stochastic ranking algorithms for estimation of kinetic parameters in biochemical pathways and networks, design of imaging sensors, optimisation of imaging processes, inverse solutions to radiative transport equations)

These state of the art techniques will provide new insights and more subtle results than is possible with standard methods; in a 'virtuous circle' challenging biosciences problems will stimulate the development of further novel analytical techniques. The work is conducted by:

- **Falciani (/staff/profiles/biosciences/falciani-francesco.aspx)** : Biosciences
- Jefferys, Young: Medicine
- **Kaban (http://www.cs.bham.ac.uk/~axk/)** , **Rowe (http://www.cs.bham.ac.uk/~jer/)** , **Styles (http://www.cs.bham.ac.uk/~ibs/)** , **Tino (http://www.cs.bham.ac.uk/~pxt/)** : Computer Science
- **Yao (http://www.cs.bham.ac.uk/~xin/)** : CERCIA

Motion and dynamics

1. Sperm movement and modelling of force generation by flagella
2. Adhesion of platelets and leukocytes to the walls of vessels for understanding of thrombosis and inflammation using fluorescent probes
3. Intravital measurement and analysis of haemodynamics, white cell adhesion and thrombus formation in live vessels

4. Micro-particle-velocimetry and motion analysis using computer vision algorithms
5. Movement of cells in biofilms
6. Visualisation of the vibration of instruments interacting with biological systems through scanning laser vibrometry (SLV)

Automatic segmentation, tracking and classification of cells and particles in large temporal image sequences is a challenging computer image analysis problem. Even more challenging is the 'event' and 'behaviour' detection where specific image sequences are given biologically meaningful interpretation (e.g. cell division, cell death). This work is conducted by:

- **Barigou (/staff/profiles/chemical-engineering/barigou-mostafa.aspx)** : Engineering
- **Gaffney (/staff/profiles/artsandlaw/gaffney-vince.aspx)** : VISTA
- **Macaskie (/staff/profiles/biosciences/macaskie-lynne.aspx)** , **Publicover (/staff/profiles/biosciences/publicover-steve.aspx)** : Biosciences
- Nash, **Watson (/staff/profiles/cem/CVRS/Watson-Steve.aspx)** : Medicine
- **Preece (/staff/profiles/chemistry/preece-jon.aspx)** : Chemistry
- **Walmsley (/staff/profiles/dentistry/walmsley-damien.aspx)** : Dentistry

Mass spectrometry imaging

With capabilities in SIMS and MALDI Mass Spectrometry (MS) imaging, a particular focus is in the improvement and development of matrix assisted laser desorption ionisation (MALDI) as a MS imaging tool for small molecules, enabling imaging of drugs and metabolites in preclinical applications. This work is conducted by:

- **Bunch (/staff/profiles/chemistry/bunch-josephine.aspx)** : Chemistry
- **Rainger (/staff/profiles/cem/CVRS/Rainger-Ed.aspx)** , Laylor: Medicine

Multispectral imaging

Non-invasive multispectral imaging is being developed and combined with other techniques to map eye histology and degeneration and blood flow in limbs. This work is conducted by:

- **Claridge (http://www.cs.bham.ac.uk/~exc/)** , **Dehghani (http://www.cs.bham.ac.uk/~dehghanh/)** , **Styles (http://www.cs.bham.ac.uk/~ibs/)** : Computer Science
- **Bunch (/staff/profiles/chemistry/bunch-josephine.aspx)** : Chemistry

Other research areas

Other research areas, which pioneer novel uses of existing imaging techniques, include:

1. Modelling, development and analysis of implants and the interfaces they form with biosystems using molecular probes, OCT, ultrasound and computational modelling
2. Interaction of biofilms with implants and metallic surfaces of medical devices and catheters using TEM, SEM, confocal microscopy and micro-MRI
3. Environment-related studies such as microbial bioremediation, characterisation of drinking water quality, measuring biochemical oxygen demand in freshwaters using confocal microscopy, multispectral imaging and computer modelling

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