Stephen Billings Research Themes

The research group supports a diverse range of multi-disciplinary research projects that span several departments and institutions. The research provides the underpinning signal processing, system identification, dynamical analysis and control of complex systems to support emerging multi-disciplinary research themes in metabolic systems engineering, systems and synthetic biology, stem cell dynamics, neuro-imaging, bio-imaging, neural processing in Drosophila, reaction-diffusion systems, non-equilibrium growth processes, studies of solar terrestrial systems, mobile robots, volatility modelling and financial systems, nonlinear materials design and many other complex phenomena.

The aims of the research are twofold: First, to elaborate developments of nonlinear signal and information processing methods from a generic systems engineering perspective. Secondly, to extend and develop the systems engineering algorithms to address the specific problems associated with each of the multi-disciplinary topics above. We expect this research to naturally evolve to include other cross-disciplinary research themes and to stimulate further collaboration between disciplines, departments and institutions.

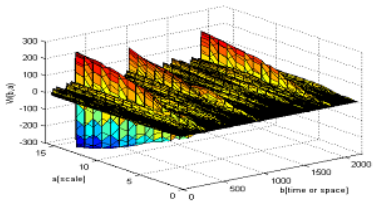
Most of the research was funded from the research councils and similar bodies.

A Selection of search Topics

Signal Processing and Complex Systems involves a diverse range of research, which includes the development of both core underlying theories and focussed application areas. Most of the research is funded from the research councils and similar bodies. A brief description of a selection of current research topics is given below.

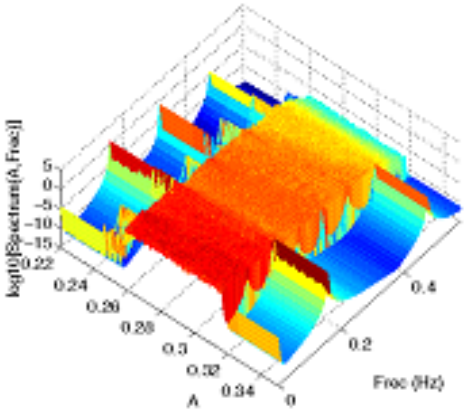
NONLINEAR SYSTEM IDENTIFICATION, SIGNAL AND INFORMATION PROCESSING

The derivation of system identification and information processing algorithms to identify both the system structure and estimate the unknown parameters in a wide class of nonlinear models including polynomial and wavelet narmax models, radial basis function and wavelet network models is being investigated. The focus is on model structure selection and the identification of models that are transparent, which can be related back to the underlying system, and which generalise well. The derivation of generic model validation and model analysis methods for all classes of nonlinear models are also being studied.



Subharmonics and Severely Nonlinear Systems

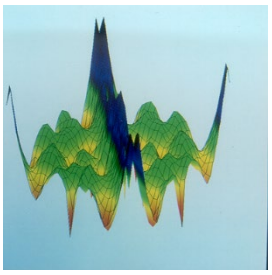
Severely nonlinear systems, which generate sub-harmonics, are being studied in both the time and the frequency domain. The Response Spectrum Map, which is a frequency domain equivalent to the Bifurcation Diagram, has recently been introduced as a powerful new tool for analysing this important class of systems.



Nonlinear Systems in the Frequency Domain

A complete theory for the analysis of nonlinear systems in the frequency domain has been developed. This consists of analytic methods for mapping from nonlinear discrete and continuous time nonlinear differential equation models to the multi-dimensional generalised frequency response functions and visa versa.

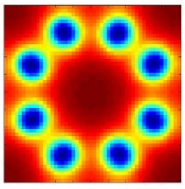
A new class of filters, called energy transfer filters, has recently been derived which allows energy to be moved to new frequency locations or spread over a band of frequencies.



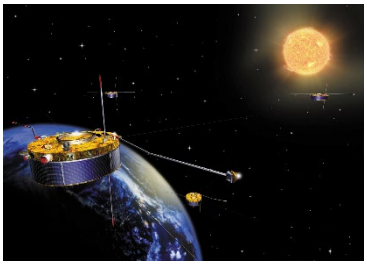
Spatio-Temporal Systems and Cellular Automata

Spatio-temporal systems are systems that evolve over both space and time. The realisation, identification, prediction and analysis of this class of systems are being studied using both partial differential equation and lattice dynamical system models.

Cellular automata (CA) and excitable media models are also being studied.



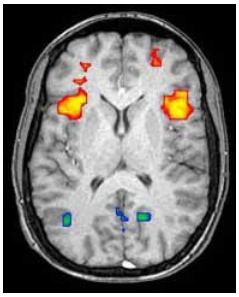
Modelling the Magnetosphere and Solar Wind



The identification and analysis of data sets relating to the magnetosphere and the solar wind, based on data recorded from satellites, is being studied in both the time and the frequency domain to forecast geomagnetic indices and to predict disturbances of the magnetic field such as storms and sub-storms

Neuro-Imaging and Systems Neuroscience

Models relating the Blood Oxygenated Level Dependent (BOLD) signal from functional magnetic resonance imaging (fMRI) and hemodynamic response to changes in neural activity, and for determining inter-regional neuronal interactions are being studied. Neuro imaging has become an important scientific technique for the investigation of brain function, and is an important example of a spatio-temporal system that has enormous potential for addressing significant issues in neuroscience and medicine.

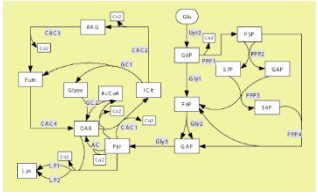


Diffuse Optical Tomography (DOT) imaging methods are also being developed.

Modelling and Identification for Mobile Robots

An investigation to determine how robot attributes, sensor properties and environmental characteristics influence robot behaviour, and the development of a theoretical framework to describe robot environment interaction is being studied.

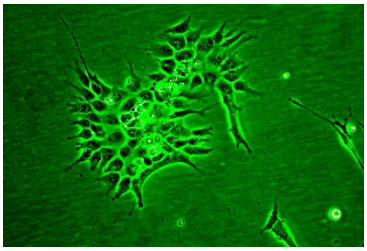
Metabolic Systems Engineering



Metabolic engineering involves the modelling and identification of metabolic pathways found in an organism to better understand and utilise cellular pathways for chemical transformation.

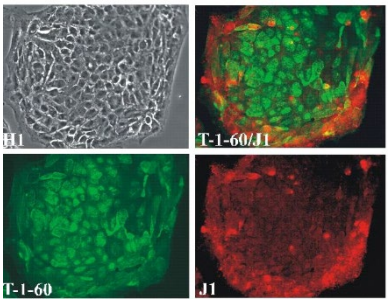
Systems and Synthetic Biology

Whereas systems biology is essentially reverse engineering of biological systems synthetic biology is the design and construction of new biological parts, devices, and systems. Ultimately the aim of synthetic biology is to be able to manipulate biological systems in a similar way that is now possible with physics and chemistry systems.



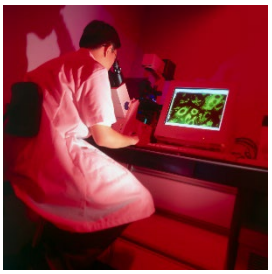
Stem Cell Dynamics

Research on stem cell dynamics, including the modelling and identification of stem cell behaviour is being investigated.



Bio-Imaging

Imaging based in the medical, pharma, biotech and healthcare sectors is being studied.

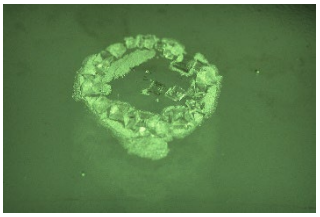


Identification and Analysis of Neural Activity and the Visual System in Drosophila

The neural processing of the visual system of Drosophila or fruit flies is being investigated.

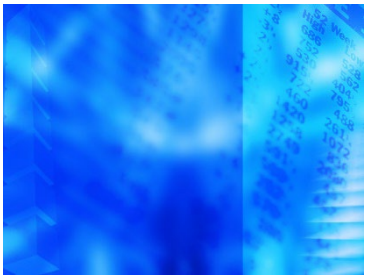
Reaction Diffusion Systems and Crystal Growth

The identification, modelling and analysis of chemical non-equilibrium growth processes, including reaction-diffusion systems, crystal growth, bacterial colonies, is being investigated.



Modelling Financial Systems

Modelling financial systems, especially market risk, is being studied.



Machine vision

The development of computer vision systems for autonomous guided vehicles (agv's) and robotics is being studied