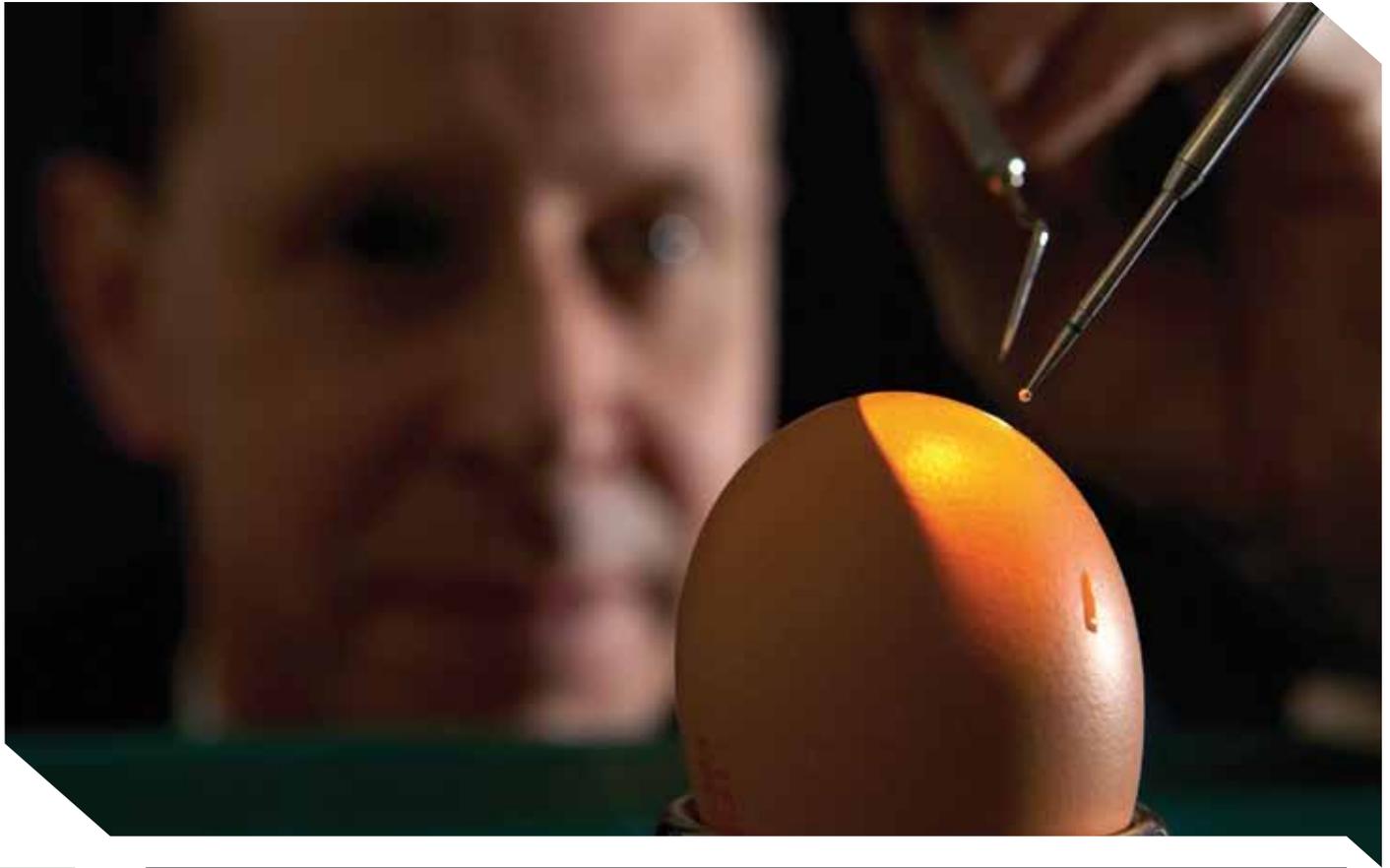




The Biomedical Engineering Research Group

**The Biomedical Engineering
Research Group**

Aston University
Birmingham



About us

The Biomedical Engineering Research Group at Aston University focuses on new medical devices that meet the needs of clinicians in practice. Current investigations are on innovative smart tools for surgery, smart bio-sensing systems, cell processing, new implants, patient monitoring and well-being assessment, mechanical cardiac support including left ventricular assist devices and on the underlying mechanics of blood flow needed to produce safe and effective solutions. The research is led by a professional team of clinicians and engineers who are producing innovative solutions in practice.

The research integrates new approaches to sensing, embedded hardware technologies; information technology and micro-manufacturing processes to produce pragmatic and cost-effective solutions suited to the health environment, clinical and patient needs. Our suite of state-of-the-art laboratories enable leading edge investigations and solutions to be produced. We work with Research Councils, other international leading research groups, medical charities and industry, and are grateful for their support that has led to new solutions for precise therapy, efficient clinical techniques and cost effective devices that widen access to healthcare.

Professor Peter Brett

Professor of Biomedical Engineering Systems

Contents

About us	2
Contents	3
Smart microsurgical tool points	5
Micro-drilling in surgery	7
Steerable digit with 'touch-sense' feedback	11
Smart monitoring and diagnosis systems in medicine	15
Distributive tactile sensing using dynamic plate properties	17
Methodology for evaluating changing states in body functions	21
Microsystems for medical diagnosis and cell discrimination	25
Micro-fluidic system for cell separation	27
Investigation on a microplate based cellular bio-sensing system	31

Cardiac-assist technologies	35
Rotary blood pump	37
Inter-positional aortic balloon pump	39
Investigation of left ventricle dynamics	41
Investigation of red blood cell dynamics in Couette flow	43
The multidisciplinary research investigation team	45
Patent details	47
Contact details	49

Smart microsurgical tool points

Over the past 20 years robotic systems have demonstrated benefits in surgical therapy with greater accuracy and consistency of tool trajectories in contrast with manual interventions. It has been a great achievement to deploy these machines in the operating theatre in close proximity to patients and staff and now commercial systems are available. Tool guidance is most often related to pre-operative scan data with possible control by the surgeon. Important steps to be made in future development of these devices are to enable tool guidance based on sensory perception at the tool-point and to produce smaller devices requiring little set-up time and other infrastructure in the operating room.

Our research work focuses on controlling tool-point interaction in small, even hand-supported devices. The potential to automatically discriminate different working conditions and state of the tool-point and tissues will increase perception by the surgeon at this small scale, and enable precise and consistent results. This will offer great benefit in the many surgical procedures that now work on small tissue targets and often through difficult access.



Currently we are investigating two generic solutions as smart tool-points:

- ▶ Smart micro-drilling systems
- ▶ Steerable digit with tactile 'touch sense'.

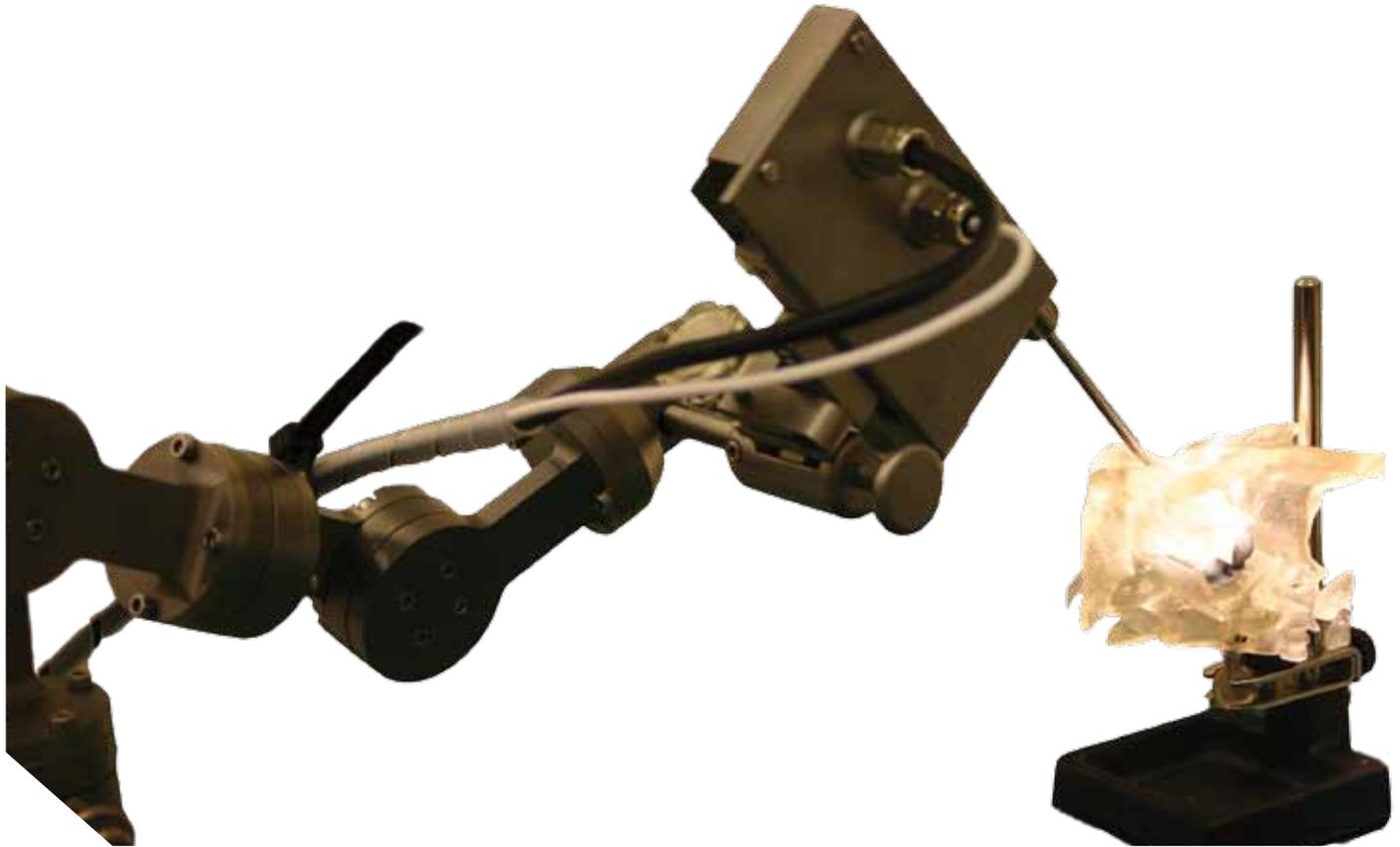
Here control is achieved through the discrimination of the interaction between tissues and tool-point. These descriptions are information having great benefit over the use of pure data. Using this approach it is also possible to infer the state of tissue and tool-point in real time.



Controlling a flexible digit with tactile feedback



Preparing the micro-drill for theatre trials



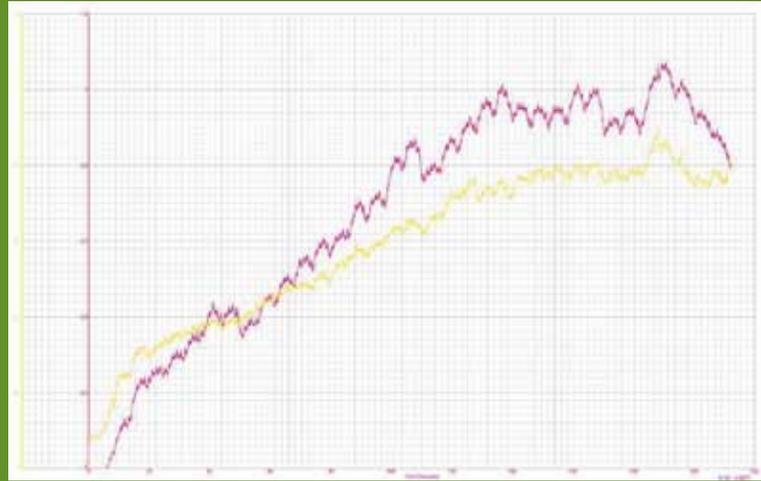
This research is producing a series of micro-drilling devices. The key is to register the tool point position with respect to tissue position automatically in real-time. Often there is a need to identify tissue types and behaviour, and to control the tool-point with respect to the detected tissue interfaces and membranes. The robotic surgical micro-drill produced is able to discriminate these conditions as different states in a process and moves the tool point autonomously to achieve consistent and precise results.

The system has been used successfully in the operating theatre and has achieved precise cochleostomies. Use of this tool has shown that precise and consistent results can be achieved efficiently. When drilling a cochleostomy the medial interface of the bone structure of the cochlea is discriminated against the delicate endosteal membrane in real-time such that the device penetrates the bone tissue without penetrating the membrane. As a result, trauma to the hearing organ is reduced, there is greater opportunity to retain residual hearing, sterility is maintained and debris can be removed before insertion of the electrode. These factors are expected to reduce the incidence of complications and are of growing importance as cochleostomies are becoming more common in patients with lower degrees of hearing loss.

This approach to drilling has many applications in surgery.



Drilling force transitions in cochleostomy



Completed cochleostomy in theatre

In More Detail

The micro-drilling system consists of:

- ▶ Drill unit comprising of precision actuators and sensing elements
- ▶ Flex and lock arm
- ▶ Hardwired control unit
- ▶ A laptop computer.

Control is via hardware. The laptop relays information on the state of the tool-point/tissue interaction. The hand held remote unit enables supervisory control.

Force and torque transients at the tool-point are interpreted automatically in real time. The relationship between transients are used to discriminate between different states in the process and these can be the condition of the tool and tissue, patient and tool movement, approach towards tissue boundaries and drill breakthrough. With this information it is possible to interpret the critical breakthrough event before it occurs and to automatically control drill penetration precisely with respect to this deforming tissue boundary.

For further information

Professor Peter Brett

p.n.brett@aston.ac.uk



The aim of this research is to develop steerable digits as tool points to aid palpation and navigation in lumen in minimal access surgery. Currently the research is leading to the construction and demonstration of mini-digits with tactile information feedback for clinical processes.

To navigate complex paths within soft tissue lumen requires an instrument that is steerable at the tip and sensitive to touch. Applications are endoscopic and laparoscopic tools; catheters; and implantable devices for therapy and diagnosis.

The investigation is based on the application of the distributive tactile sensing technique where a few sensing elements are embedded in the structure of the device. In this approach the structure of the mechanism becomes a transducer of high resolution, retrieving information on motion and able to discriminate the path followed, the nature of contact and tissue characteristics such as stiffness. The technique has advantages in robust construction and mechanical simplicity. Solutions have the potential to be disposable.



In More Detail

The tool will provide tactile information feedback to the surgeon during precise surgical tasks, working through minimal access. Important information retrieved by the digit can be used to map lumen in real time. The distributive sensing approach is used to discriminate, the texture, stiffness, sliding velocities, position with respect to tissues, and the shape of the digit.

The research is investigating the merits of the sensing approach over a range of sizes from that of the human digit down to sub millimetre in diameter. This solution is suitable for implantable devices, surgical and diagnostic tools.

For further information

Professor Peter Brett

p.n.brett@aston.ac.uk

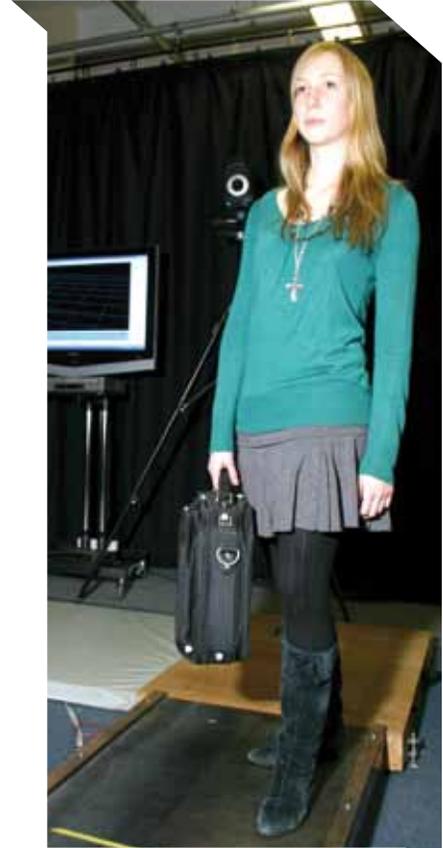
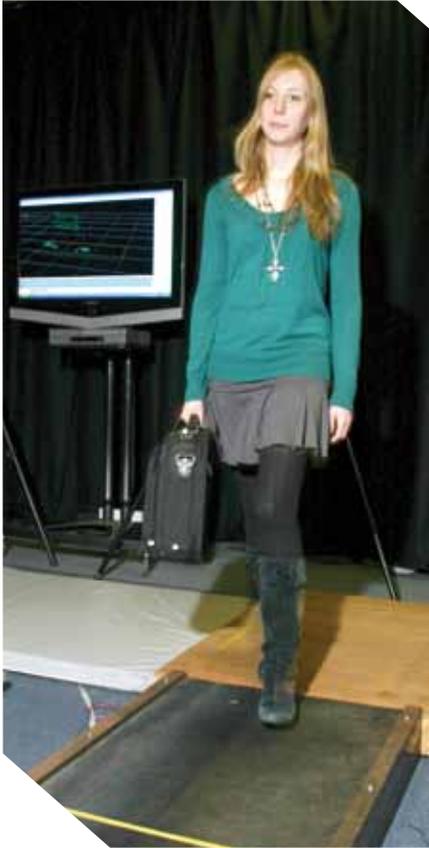
Smart sensing systems are needed that output information suited to clinical use to support the busy practice of medicine. In all cases, a smart sensing system needs to discriminate the possible series of conditions related to the application range. Sensors should be mechanically simple and robust to suit the arduous medical working environment while also being cost-effective through enabling staff to work efficiently. At one level smart sensing instruments are needed to provide information to assist in diagnosis and monitoring in critical care rather than outputting data that requires time consuming processing by clinical staff. A system may track the state of a patient and alert changes in state, or critical stages, and may form part of a bed chair or instrument used to help the patient or clinician. At the opposite level of operation in healthcare, smart sensing systems can empower patients to monitor themselves. In these applications the devices will need to be intuitive to use and may be integrated into daily living as a walking aid or mat.

Already monitoring devices to measure temperature or CDV metrics are commercially available. However, these produce data values that on their own do not provide information on well being, progression on a pathology, or the discrimination of pathologies. Smart sensing systems could provide elementary advice on improvements in technique or ritual in daily living. Information at output also enables efficient storage of types of event or condition and can be transmitted more efficiently than data. This is compatible with devices for remote use and with health information systems on the internet.

In the investigations sensory systems have been implemented that integrate leading edge signal processing techniques with IT tools to interpret multiple coupled sensory data time series:

- ▶ The versatile distributive approach to sensing applied to discriminate metrics and behaviour.
- ▶ A methodology for evaluating changing state in body functions used to detect the onset of muscle fatigue.

Distributive tactile sensing using dynamic plate properties



This research is investigating the smart distributive tactile sensing technology and other leading edge signal processing techniques to discriminate human gait and balance information from the dynamic response of a flexible surface. In contrast with other technologies for sensing human movement, this research is leading to devices that are mechanically robust, efficient to construct and able to discriminate the types of motion of people on the surface.

To date the method has been successfully applied to discriminate movement in sport and health monitoring.



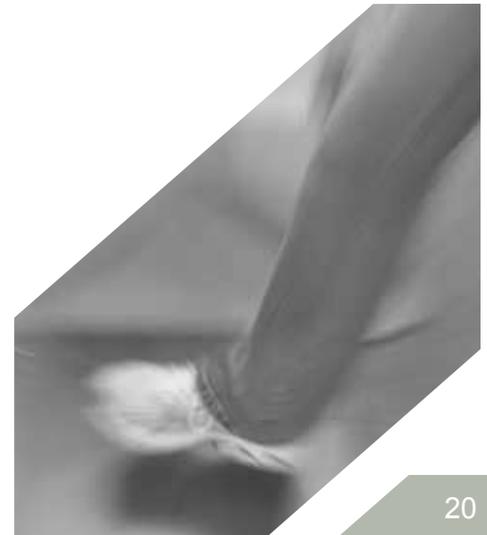
In More Detail

A VICON Motion Capture system serves as a reference to capture the motion of a subject moving over the surface and to confirm the output of the new tactile approach to sensing.

This efficient approach to sensing is appropriate to a wide range of application sectors, such as manufacturing and food automation, where there is a need to automatically discriminate variable products, their location and behaviour, based on contact. The method produces solutions suited to harsh working environments.

For further information

Professor Peter Brett
p.n.brett@aston.ac.uk





This research has derived and evaluated an automated generic identification method that can be applied to evaluate the state of body functions using coupled Electromyographic (EMG) signals in real time and in the time domain. The method is based on the premise that functions of the body are non-linearly coupled, complex and dynamic. System parameters are derived to detect and predict changes, and limiting factors.

The investigation has studied the onset of fatigue during lengthy microsurgical procedures. It is difficult for the individual to assess their relative change in performance over time and this is a crucial factor as many procedures conclude with a final, precise and critical task.

The project is developing new methodology and algorithms that can be used to analyse and measure hand tremor and fatigue of surgeons in practice. The complexity method, Principal Component Analysis, the Empirical Mode Decomposition algorithm and non-linear Auto Regressive with exogenous inputs NARX neural networks have been used during development of the system.



In More Detail

Surface electrode EMG data is captured and analysed for defining patterns. Muscle fatigue is generally determined by examining differences in EMG signals and the Power Spectral Density (PSD) through the shift in mean frequency and the corresponding decrease in power level. Lower frequencies arise from physiological tremors in muscles that are associated with the lower energy levels of slower muscle activation.

When near to fatigue, precise finger motion deteriorates and resulting tremors adversely affect performance. By coupling simultaneous EMG and accelerometer signals a sensitive approach to identify the onset of fatigue and tremor has been produced. The complexity of the signals is a powerful means to interpret fatigue. The approach characterises complexity from the singular values and entropy of time-series signals and patterns corresponding with decreasing entropy are used to interpret approaching fatigue.

In the approach used during surgery, Principal Component Analysis and Empirical Mode Decomposition were applied in combination to hand tremor signals. NARX neural networks were used to predict trends during surgery that indicate deteriorating performance.

For further information

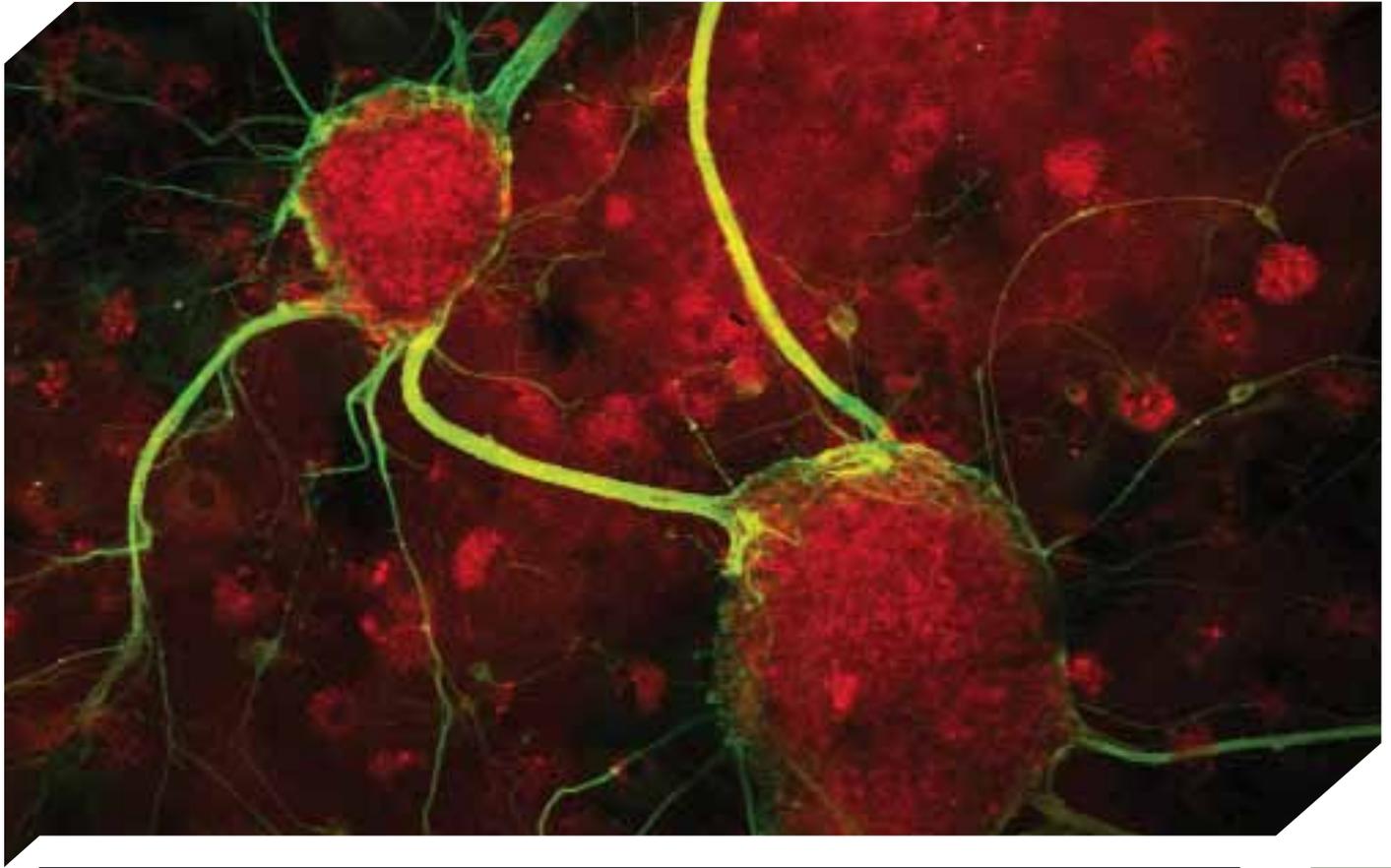
Dr Xianghong Ma
x.ma@aston.ac.uk

Micro-technologies in the form of MEMS have made an impact on solutions for active sensing in healthcare and other application fields. Building on this technology and combining novel sensing and signal processing technologies, the research aims to produce advanced information sensors capable of outputting information and discriminating measurements on a sub-micron basis. The techniques will combine novel sensing methods, MEMS and Nanotechnology. Working at this scale to discriminate distributive cell behaviour, characteristics and structure will enable greater understanding of cell processes and offer opportunities to improve healthcare.

Possibilities include powerful devices to discriminate diseases in real time and offer new therapies that are currently difficult or impossible to achieve.

Two examples studies are described:

- ▶ A micro-fluidic system for cell separation
- ▶ A microplate based cellular bio-sensing system.



Confocal fluorescence imaging of cells



This research focuses on developing a microsystem for biological cell manipulation to assist the Intracytoplasmic Sperm Injection, (ICSI). procedure in reproduction therapy.

In severe male factor infertility there is an absence of active spermatozoa in ejaculate samples that can be used for the ICSI process. However, considerable success has been achieved using cells harvested directly from the testis via biopsy. Biopsy samples contain a wide variety of structural cells and germ cells and ICSI requires mature germ cells that have been sorted from other cellular debris.

This project has applied semiconductor microfabrication manufacturing techniques to develop advanced micro-scale tools for collecting useful cells automatically. This will both reduce the skill and time required to locate, identify and prepare the germ cells for the ICSI procedure.



In More Detail

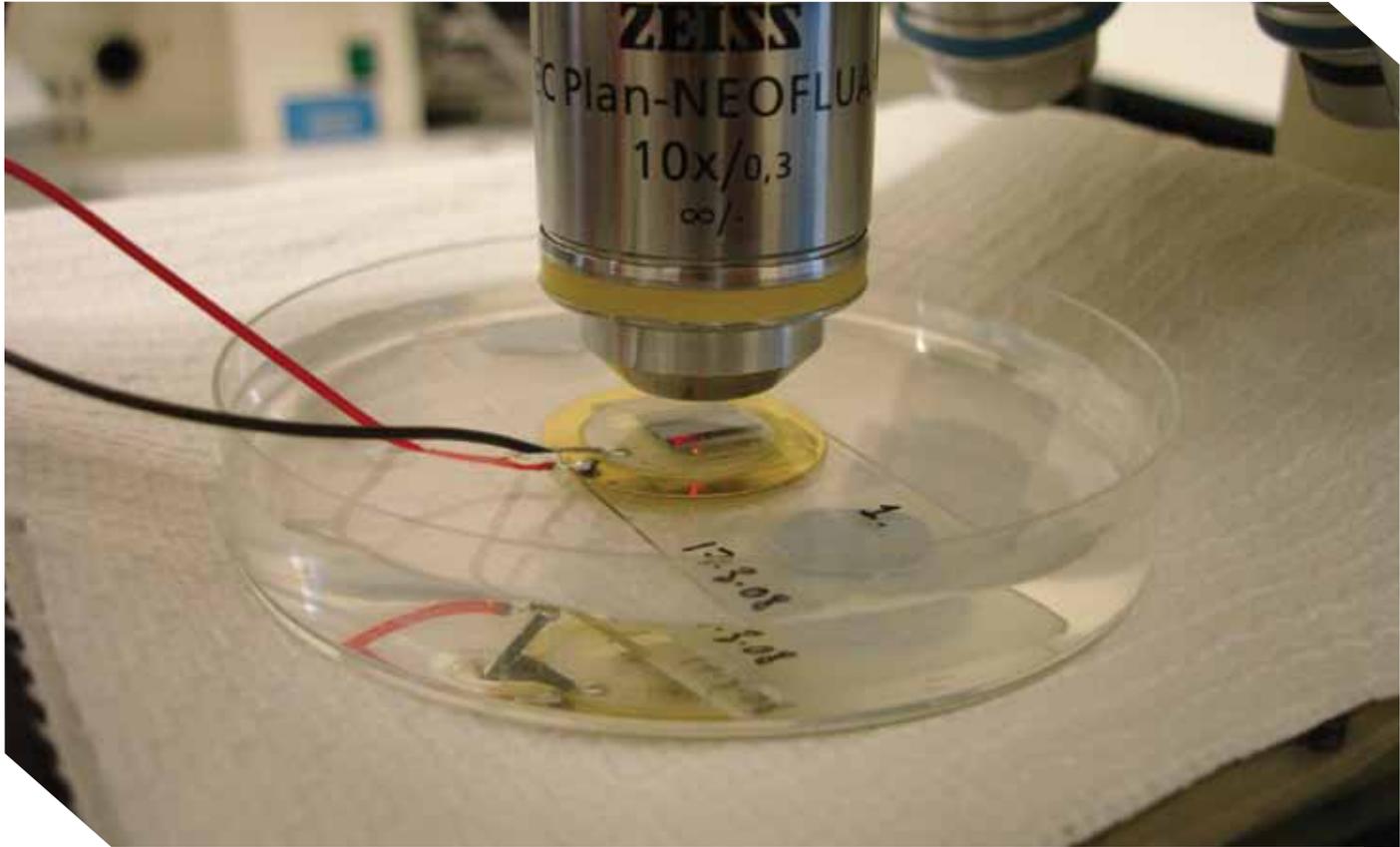
Surface electrode EMG data is captured and analysed for defining patterns. Muscle fatigue is generally determined by examining differences in EMG signals and the Power Spectral Density (PSD) through the shift in mean frequency and the corresponding decrease in power level. Lower frequencies arise from physiological tremors in muscles that are associated with the lower energy levels of slower muscle activation.

When near to fatigue, precise finger motion deteriorates and resulting tremors adversely affect performance. By coupling simultaneous EMG and accelerometer signals a sensitive approach to identify the onset of fatigue and tremor has been produced. The complexity of the signals is a powerful means to interpret fatigue. The approach characterises complexity from the singular values and entropy of time-series signals and patterns corresponding with decreasing entropy are used to interpret approaching fatigue.

In the approach used during surgery, Principal Component Analysis and Empirical Mode Decomposition were applied in combination to hand tremor signals. NARX neural networks were used to predict trends during surgery that indicate deteriorating performance.

For further information

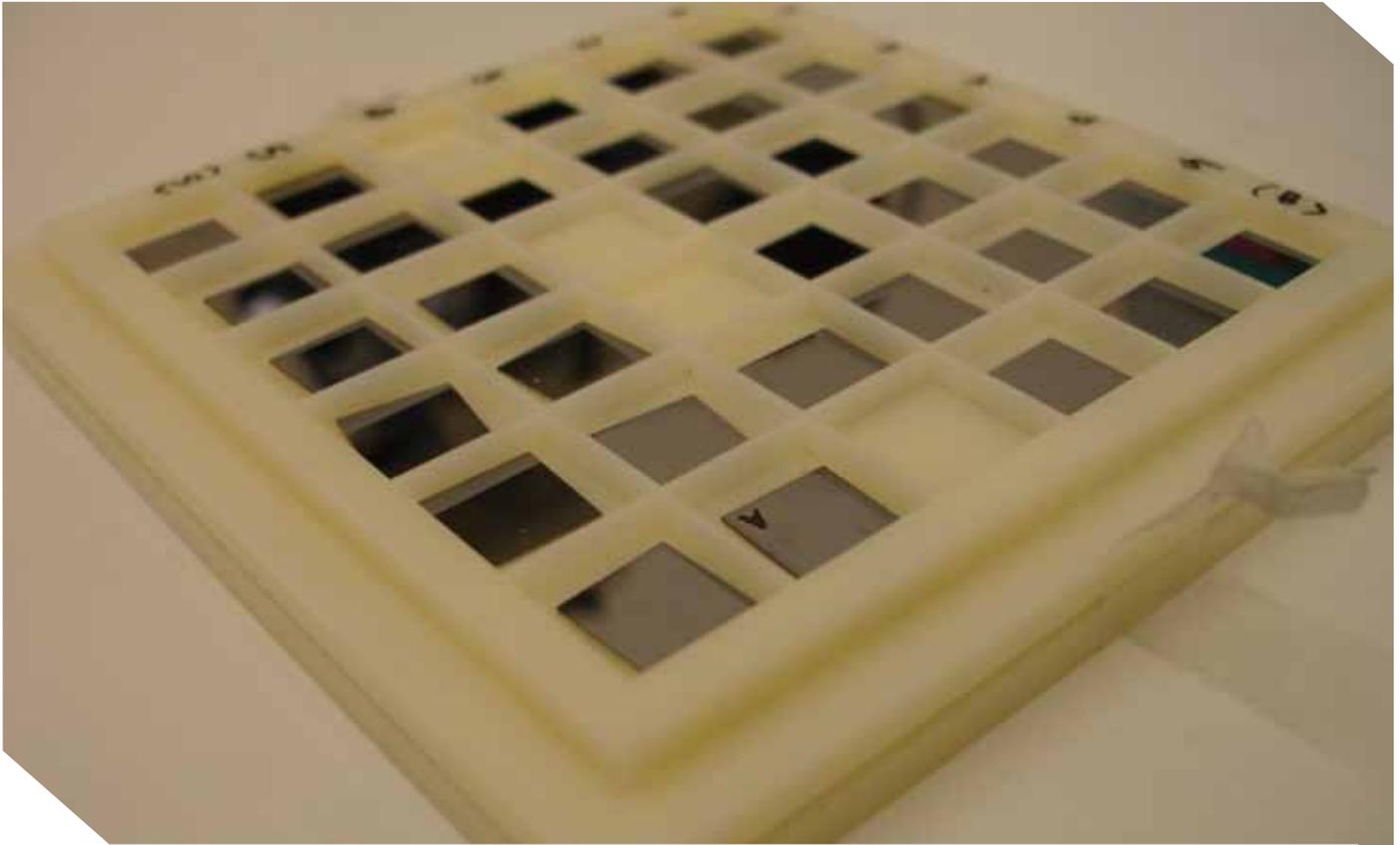
Dr Xianghong Ma
x.ma@aston.ac.uk



This research is producing a novel bio-sensing system (BioMEMS) for real time detection of cell behaviour during cell culture and growth processes. The concept is a micro-scale version of the distributive approach to tactile sensing that has been applied extensively at the large scale of the body. However at this small scale there are a number of practical and algorithm based differences.

Driven by the rapid development of MEMS technologies, design and rapid manufacture of ultra-sensitive and economical biosensors for cell detection, clinical pathology and pharmacological analysis becomes possible. Current micro-machined cantilevers enable clinicians to make such measurements, however their 1D structure is fragile and expensive to produce.

In this research 2D detection structures that will provide real time spatial distributive information relating to cells and cellular system characteristics, behaviour and structure are under investigation.



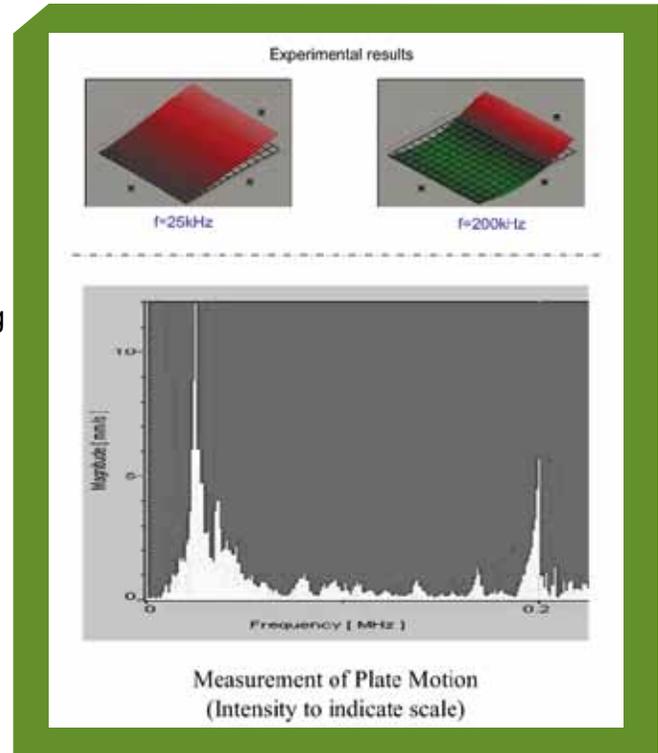
In More Detail

The design of this system consists of a micro-machined silicon plate with strategically located actuators and sensors that take into account the dynamics and sound radiation of the plate at the micro-scale in a fluid environment. Nonlinear system identification methods to discriminate size, shape, position and spatial mass contact distributions over the surface are being developed. The selection of design parameters is through computer simulation and measurement with visualisation of tests via an integrated combination of a micro-scanning laser vibrometer and confocal microscopes.

Applications are in disease discrimination, monitoring patient response to drug therapy, the investigation of cell behaviour, properties, collective structure and characterisation as a discriminative measuring system.

For further information

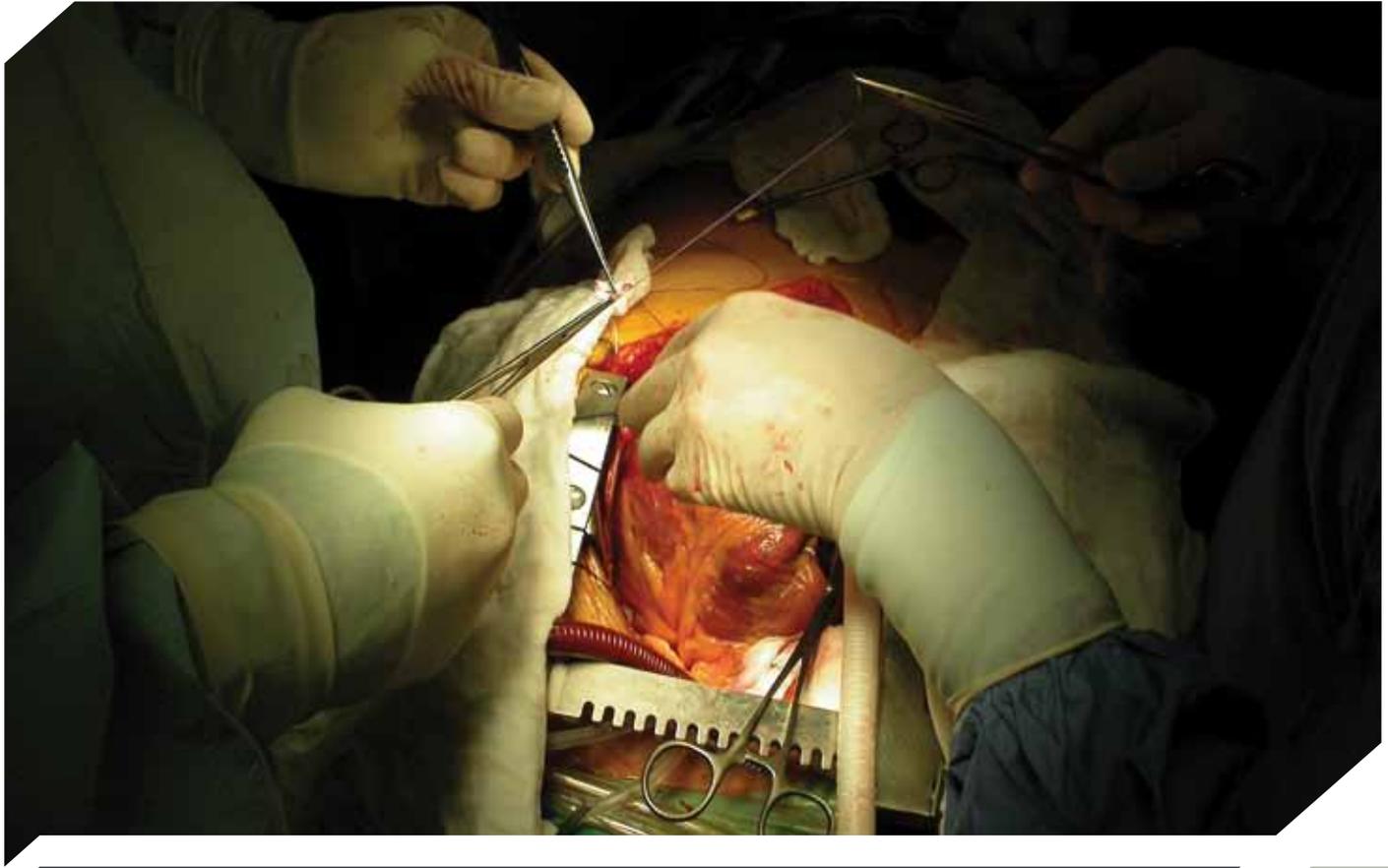
Dr Xianghong Ma
x.ma@aston.ac.uk



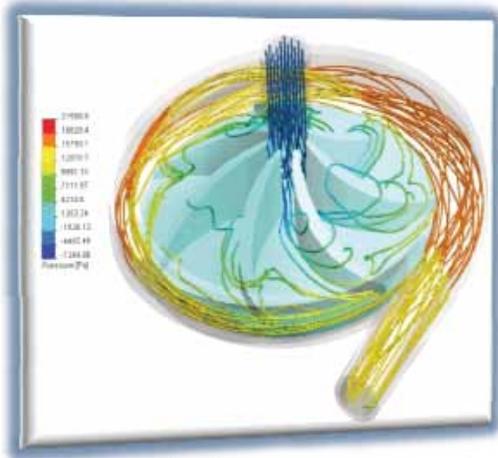
There is a need for new devices and therapies to treat cardiovascular disease. Our research is leading to new solutions in practice - based on the latest understanding of the fundamental processes involved. Behaviour in tissue biomechanics and biofluid dynamics place important demands on the design of compatible solutions. New materials, manufacturing processes, instrumentation and techniques for analysis provide the ingredients for a fresh investigation of the opportunities to produce effective devices at a reasonable cost. These solutions stand to transform the lives of patients.

Current projects presented here are:

- ▶ a rotary blood pump
- ▶ an aortic balloon pump
- ▶ an investigation of left ventricle dynamics
- ▶ an investigation of red blood cell dynamics in Couette flow.



Sternotomy - access to the heart for implantation surgery.



CFD of rotary blood pump
- assessing haemolysis.

A patients whose heart is failing may benefit from a left ventricular assist device (LVAD) which supports the ventricle of the heart by adding energy to the blood.

LVADs are used as:

- ▶ bridge to recovery – up to 90 days whilst the heart is treated or recovers
 - ▶ bridge to transplant – keeping the patient well whilst a donor heart is found
 - ▶ destination therapy – permanent therapy where a patient cannot receive a heart transplant.
- The most versatile type of VAD is the implantable rotary blood pump – a small pump which is implanted into the chest passing blood from the left ventricular apex to the ascending aorta.

This research is developing a low-cost implantable rotary blood pump with a unique hydrodynamic/ magnetic bearing. Recipients of this device will be able to leave hospital and lead a relatively normal life – albeit in constant companionship with a bag containing a controller and batteries.

In More Detail

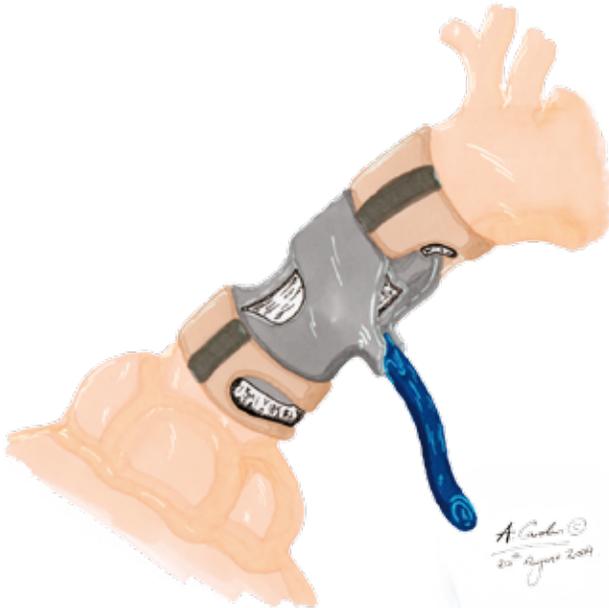
The design is based on a low specific speed centrifugal pump which incorporates a semi-open impeller with magnets in the lower shroud. These magnets are used as part of the magnetic bearing system as well as in the drive system – they cause the rotor to spin under the action of a rotating magnetic field set up by coils in the pump housing. In addition, a hydrodynamic bearing is incorporated in to the lower surface of the shroud. This configuration allows the rotor to ‘float’ in the blood and not need mechanical bearings or seals which generate heat and cause haemolysis (the destruction of red blood cells).

Some advantages this design has over already commercial rotary blood pumps are:

- ▶ the semi-open rotor configuration allows better fluid dynamics on the rotor and thus improved efficiency – this means the patient will carry lighter batteries as he goes about his daily life.
- ▶ The design requires much reduced manufacturing tolerances thus enabling it to be injection moulded and to use off-the-shelf components which will drastically reduce its cost and make it available to all health care providers

For further information

Professor Geoff Tansley
g.d.tansley@aston.ac.uk



Concept sketch of
implanted aortic
balloon pump.

Balloon pumps are used in the aorta to aid the left ventricle:

- ▶ in an acute situation, an intra-aortic balloon pump (IABP) may be used to maintain blood flow in an emergency or following cardiac surgery when the left ventricle is too weak to deliver the blood-flow needed and to maintain coronary artery perfusion (to prevent heart attacks). IABPs are rapidly deployable on the end of a cannula – usually via the femoral artery, but the patient must remain in bed so as not to damage the cannula; they cannot be used chronically.
- ▶ extra-aortic balloon pumps (EABPs) are a chronic alternative – the balloon is attached to the outside of the aorta and inflated and deflated in anti-phase with the ventricle. However EABPs have a tendency to migrate and to rupture plaques within the aorta.

We are developing a chronic, ambulatory alternative – the inter-positional balloon pump – which will be placed in the inner wall of the aorta.

In More Detail

The inter-positional balloon pump has distinct advantages over other balloon pumps through allowing the patient to be ambulatory and ameliorating the likelihood of plaque rupture, poor peripheral perfusion and balloon migration.

The inter-positional balloon pump is designed to be used in a chronic situation and has no arterial cannulation; this allows the patient to be ambulatory, go home and live reasonably normally. The patient will carry a small power pack and controller which will cause the balloon to inflate and deflate in counterpulsation with the natural heart. The inter-positional balloon pump will be permanently implanted, but may be turned off when not needed and thus used intermittently as and when the patient requires a 'boost'. The device will augment coronary artery flow (to reduce the likelihood of heart attack) and will help to reduce the size of the over-inflated left ventricle making it more able to pump blood – some patients might fully recover heart function.

Research is focused both on developing the device itself (implantables + controller) and also on the surgical and clinical protocols for a rather unique therapy. The disciplines involved in the research include mechanical and electronic engineering, product design, perfusion and surgery.

For further information

Professor Geoff Tansley
g.d.tansley@aston.ac.uk



Mock ventricle in circulatory loop: a test facility for cardiac devices.

The effect of using a mechanical support device – rotary blood pump or balloon pump – on the left ventricle is profound. The dynamics of contraction and filling of the left ventricle are markedly altered such that:

- ▶ the aortic valve might fail to open which could lead to clotting in the aortic root
- ▶ an apical cannula can interfere with or damage the interventricular septum
- ▶ the ventricle might suck-down around a cannula and occlude flow in to the cannula
- ▶ blood might clot over the entrance to the apical cannula and occlude blood flow in to it
- ▶ partial prolapse or leakage of the aortic valve might occur.

Cardiac-assist technologies

In More Detail

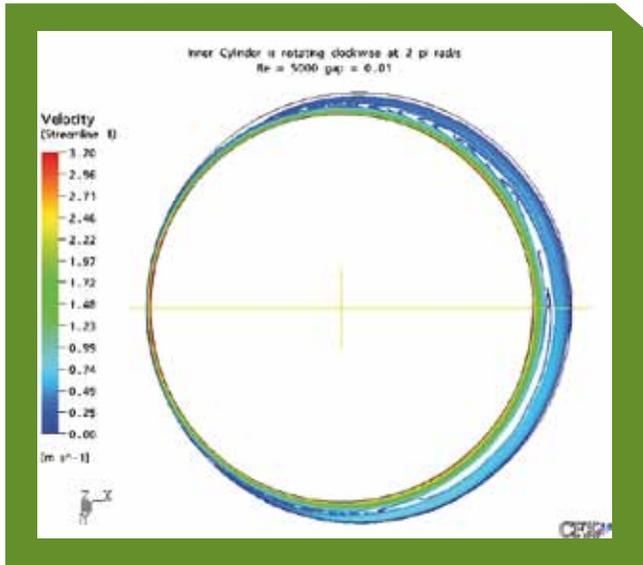
This research programme investigates ventricular dynamics on the bench. A mock loop incorporating a pneumatically controlled left ventricle is used to emulate the hydrodynamics of the systemic circulation.

Cardiac contractility and mechanical support ratios are varied in order to map allowable operating space for the support device. Particle Image Velocimetry (PIV) and Computational Fluid Dynamics (CFD) are used to investigate flow patterns within the ventricle to reduce the likelihood of clotting.

We are currently investigating the use of more realistic ventricle and aorta shapes derived from CT scans of healthy and heart-failure patients and more realistic contraction mechanics and pneumatic control algorithms. The outcomes from this research are likely to be better algorithms for the control of ventricular assist devices, and better cannula designs.

For further information

Professor Geoff Tansley
g.d.tansley@aston.ac.uk



Flow velocities in micro-couette gaps.

When blood flows in capillary tubes of less than $300\mu\text{m}$ diameter its viscosity is less than might be expected and the proportion of red blood cells (haematocrit) is also reduced. These observations are well known for Poiseuille flow (flow which is driven by pressure variation along a tube), but these mechanisms in Couette flow (flow in a small gap between a moving boundary and a stationary boundary) are mostly unknown.

An understanding of red blood cell dynamics in these circumstances is important as this affects the design of rotary blood pumps. If a red blood cell is exposed to high shear stresses its membrane will rupture and the cell contents lost (a process known as haemolysis). There is evidence (as yet untested) that red cells might be excluded from very small gaps in rotary blood pumps meaning that these cells cannot be lysed, but also that the viscosity of the blood in the bearings will be lower than might be expected and the bearing forces developed by blood bearings will be weaker than anticipated.

Cardiac-assist technologies

In More Detail

In this research programme we aim to measure experimentally the extent of red cell exclusion as a function of gap and speed and to develop a description of the mechanical forces and processes at work on red cell suspensions.

Another major outcome of the project will be an assessment of design factors in blood bearings and their influence on haemolysis.

The ultimate aim is to develop guidelines for the correct configuration of Couette gaps and blood bearings for rotary blood pumps.

The research approaches used include laser-based diagnostics of experimental blood flow (PIV), computational models both of particulate flow and of continuum fluid flow and analytical models of particulate flow.

For further information

Professor Geoff Tansley
g.d.tansley@aston.ac.uk

Professor Peter N. Brett
Professor of Biomedical Engineering
p.n.brett@aston.ac.uk

Professor Michael Wright
Emeritus Professor
+44 (0)121 204 4881

Dr Xianghong Ma
Senior Lecturer
x.ma@aston.ac.uk

Dr Xinli Du
Research Associate
x.du@aston.ac.uk

Professor Geoff Tansley
Professor of Mechanical Engineering
g.d.tansley@aston.ac.uk

Dr David Holding
Reader in Electronics
d.j.holding@aston.ac.uk

Dr Mark Prince
Lecturer
m.prince1@aston.ac.uk

Dr Jing Zhao
Research Assistant
j.zhao1@aston.ac.uk

Professor Derek Alderson, FRCS
Professor of Surgery
University of Birmingham,
Birmingham

Mr Chris Coulson, FRCS
ENT Consultant
Queen Elizabeth Hospital,
Birmingham

Professor Mansel Griffiths, FRCS
Senior Consultant in ENT Surgery
St Michaels' Hospital,
Bristol

Mr Richard Irving, FRCS
Consultant ENT surgeon
Queen Elizabeth Hospital,
Birmingham

Professor David Proops, FRCS
ENT Consultant Surgeon
Queen Elizabeth Hospital,
Birmingham

Mr Andrew Reid, FRCS
Consultant ENT Surgeon
Selly Oak Hospital,
Birmingham

Mr David Richens, FRCS
Consultant Cardiac Surgeon
University Hospitals,
Nottingham

Ms Olga Tucker, FRCS
Consultant Surgeon in General Surgery
Queen Elizabeth Hospital,
Birmingham

Mrs Konstance Tzifa, FRCS
Consultant ENT surgeon
Children's Hospital,
Birmingham

Micro-drilling in surgery [p.8-10]

Improvements in or relating to drilling apparatus and methods

Granted: -

Pending: AU 2007262727
CA 2655778
EP 07733340.9
US # TBA

Priority Claimed: Jun 22, 2006

Our Ref: PAT-2006-002

Smart Bone Anchored Hearing Aid Insertion System

Granted: -

Pending: GB 0911232.7
Priority Claimed: Jun 10, 2009
Our Ref: PAT-2009-007

Distributive tactile sensing using dynamic plate properties [p.18-20]

Dynamic Sensing System

Granted: US 7,406,386

Pending: AU 2004425280
CA 2531788
EP 04742205.7
JP 518361/2006

Priority Claimed: Jul 9, 2003

Our Ref: PAT-2004-008

Automatic Discrimination of Dynamic Behaviour

Granted: -

Pending: PCT/GB2008/002037
Priority Claimed: Jun 15, 2007
Our Ref: PAT-2007-010

Investigation on a microplate based cellular bio-sensing system [p.32-34]

Characterising properties or behaviour of biological cells

Granted: -

Pending: GB 0911331.7

Priority Claimed: Jun 30, 2009

Our Ref: PAT-2009-006

Rotary blood pump [p.37-38]

Rotary Blood Pump

Granted: -

Pending: GB 0816883.3

Priority Claimed: Sep 15, 2008

Our Ref: PAT-2008-006

Inter-positional aortic balloon pump [p.39-40]

Pulsatile Blood Pump

Granted: -

Pending: PCT/GB2008/003309

Priority Claimed: Sep 28, 2007

Our Ref: PAT-2008-005

General enquiries

The Biomedical Engineering Research Group
School of Engineering and Applied Science
Aston University
Aston Triangle
Birmingham
B4 7ET

Telephone: +44 (0)121 204 3563

Fax: +44 (0)121 204 3863

More information

The Biomedical Engineering Research Group website
www.aston.ac.uk/eas/research/groups/biomedical

General enquiries

Darian Brookes
IP Business Development Manager

Business Partnership Unit
Aston University
Aston Triangle
Birmingham
B4 7ET

Telephone: +44 (0)121 204 4257
Fax: +44 (0)121 204 5152
Email: d.brookes@aston.ac.uk
Skype: [darian_brookes_work](#)

More information

The Business Partnership Unit website
www.aston.ac.uk/bpu

The Biomedical Engineering Research Group

The Biomedical Engineering Research Group

www.aston.ac.uk/eas/research/groups/biomedical