Projects approved for EPSRC IAA Funding up to 1 September 2017

TECHNOLOGY FUND

PI: Jason Smith

Department: Materials

Title: Scaling up nanoparticle sensors based on open microcavities

Nanoparticles (NP's) are widespread in research ranging from medical, physical, biological chemical and environmental sciences, and are increasingly important in industrial applications and processes. Many of these applications involve nanoparticles suspended in a fluid environment, and so there is a considerable and growing market for instruments that can detect and characterise nanoparticle in fluids.

Our team has recently developed unique NP sensors capable of trapping and characterization (size, shape and refractive index) of single NP's using optical microcavities. The closest competing technology is Nanoparticle Tracking Analysis (NTA), a technique developed by Nanosight in 2002 which is one of a handful of techniques (Resonant Mass Measurement and Tunable Resistive Pulse Sensing being the others) for analysing single nanoparticles in a liquid solution. Importantly, none of these techniques can extract any anisotropic properties, essential for a range of applications such as nanotoxicity, drug delivery or virus characterization. Our microcavity-based technique can naturally access the anisotropic properties of NP's so that shape measurement of NPs in fluids constitutes a key value proposition for commercialisation of this technology.

We are pursuing this work in partnership with leading nanoparticle analysis company Malvern Instruments. We have obtained first proof-of-principle data and are now looking towards the construction of a prototype instrument. However before this construction begins there is an important question of scalability to address. Successful usage of the prototype will require an instrument throughput of some 1000 nanoparticles per hour so that statistical data can be retrieved, and our current experiments achieve only about 20 nanoparticles per hour. Here we propose work packages to address this challenge and thereby move the technology closer to venture capital investment and commercialisation.

PI: Georg Gottlob

Department: Computer Science

Title: Ratiolytics: A Rule-based AI System for Reasoning, Data Wrangling and Analytics

Large enterprises store massive amounts of data, from which they wish to infer knowledge (at times in combination with external datastores) to improve their decision making. For instance, a bank wants to detect fraudulent transactions or decide whether a customer is creditworthy. A retail company would like to optimise their pricing decisions based on both internal data (e.g historic sales records) and external data (current product prices of competitors) available on the Web. The steps needed to query the data are (1) data provisioning: to perform preparatory data wrangling tasks by selecting relevant data from various internal and external sources, transforming and merging the data, and storing the data in appropriate tables into a database; (2) data analysis using machine learning, data mining methods, or logic reasoning and (3) drawing inferences to make business decisions. In the context of the VADA EPSRC-funded project, we are developing a novel unified methodology to do (1), (2), and (3) within a single rule-based system, and we have built a pilot prototype of such a system. Our technology is based on the data-processing language Datalog and the concept of transducers. Recent extensions of Datalog developed in our group have successfully demonstrated a good trade-off between expressive power and computational efficiency. Despite the early stage of development, our methods and initial system have attracted strong interest from diverse industrial contacts, especially in the banking and security areas. Having attested there is a great need for such systems, our goal is to spin out a company (Ratiolytics) in the future.

PI: Justin Coon

Department: Engineering

Title: Advanced Modulation for Spectrally Efficient Communication

The proposed project relates to a new method of communicating digital information between two electronic devices, such as smart phones and base stations, laptop-to-laptop, etc. The method is known as discrete cosine transform orthogonal frequency-division multiplexing with index modulation (DCT-OFDM-IM). This method, which was recently invented in the Oxford Communications Research Group, has the potential for achieving spectral efficiency gains (measured in units of bits per second per Hertz) of more than 60% relative to state-of-the-art benchmarks currently used in 4G cellular communications, Wi-Fi, and digital video broadcast (DVB) systems. The overarching goal of this project is to develop a proof-of-concept demonstration of DCT-OFDM-IM in a practical setting using state-of-the-art development equipment.

PI: Mark Thompson

Department: Engineering

Title: Biosolenoid for tissue engineering and drug discovery applications – mechanobiological force control for bioreactors

Healthy cellular tissues require and adapt in response to mechanical forces. The underlying science, mechanobiology, explains why the bones in tennis players' serving arms are stiffer and stronger than the non-serving side and allows astronauts to stay healthy in microgravity thanks to special physical exercise regimes.

Biosolenoid technology has been previously developed by our lab with an aim to harness mechanobiology in vitro to deliver:

- in vitro models for drug discovery with a mechanical environment
- stronger, more organised engineered tissues
- a precision force application for basic mechanotransduction research

The Biosolenoid technology is unique in that it combines electromagnetic field shaping with bioreactor design to provide precision contactless mechanical stimulation requiring no physical breach of the sterile envelope.

The additional proof of concept experiments proposed in this grant, will further assess the viability of this technology for a wide range of possible applications within these three key areas. A collaborative development process is proposed with a bioreactor manufacturer who will provide access to proprietary IP and additional expertise in the drug discovery space. The proposed proof-of-concept experiments will de-risk further investment and increase licensing opportunities with commercial companies that have already expressed an interest.

PI: Richard Berry

Department: Physics

Title: A simple miniature epi-illuminator to integrate four advanced light microscopy techniques

We have developed (patent pending) a light microscopy technology, which is based on a simple optical design and enables integration and miniaturization of four powerful advanced techniques in a low-cost attachment. Of these four epi-fluorescence, interference reflection contrast and dark field surface reflection have limited availability to non-specialist users due to their high costs, while back-scattering dark field is not available commercially and requires custom modifications of existing commercial microscopes.

Only one modular device is needed to add all these techniques to a standard microscope. We aim to substantially improve and refine the design of the prototype to make it usable on any commercial microscope, and then develop a portable low-cost near-market version of the device for non-specialist users. We expect that our technology will expand availability of these techniques to a broad audience, including among others public health and educational sector and budget-tight organisations.

PI: Harish Bhaskaran

Department: Materials

Title: Next generation computer memories – using light to store data

Prof Bhaskaran is the PI of the EPSRC Funded WAFT Collaboration (EP/M015173/1, £3.1 Million), which also includes co-investigators from the Universities of Southampton and Exeter, as well as 15 industrial partners including BASF and IBM. In addition, he is also Oxford lead investigator on the £3.1 million CHAMP Partnership (EP/M015130/1), which includes Cambridge, Heriot Watt, Exeter and Southampton, and several industrial partners. Through both of these grants and several other EPSRC projects (including his current manufacturing fellowship, EP/J018694/1), Prof Bhaskaran has developed the world's first photonic memories, as well as techniques to store multiple bits of data on single memory devices. The same devices have also shown to be capable of the first non-von Neuman on-chip arithmetic (where the processing and memory are co-located). Some basic patent protection has also been sought (UK patent applications, filed by Oxford University Innovation). However, to create impact of this requires several device iterations and testing of the so-called "drift" effect, a well-known effect that changes the value of a memory. This is impact-oriented research that falls exactly in a 'black-hole' where it is too advanced for EPSRC funded 'standard' research (which is oriented to basic science studies, most of which we have done), but too early stage to create impact either via commercialization, or through others adopting this work as the entire set of materials and device dimension parameter space has not yet been explored. This is hence the focus of this proposed Technology Fund Application, precisely because it addresses this "valley of death" problem. In this project we will employ a Research Impact Engineer to take our laboratory techniques and develop the entire parameter space that will specifically help translate our research outputs to increase impact of our scientific work, while reducing lead-times for such a technology to be taken seriously in industry.

PI: Peter Edwards

Department: Chemistry

Title: "Smart" materials vs thermally-insulating hybrids for regulating building temperature

Nanometal oxide/polymer hybrid technology is being developed at Oxford for the control of infrared (IR) radiation. There are a number of attractive markets for this innovation including smart windows for the reduction of cooling costs in buildings, infrared camouflage in defence, and lightweight clothing for cold conditions. This project seeks to significantly de-risk aspects of the technology commercialisation, and hence make investment into a new company to exploit the technology more attractive.

PI: Tom Melham

Department: Computer Science

Title: CREST - C REference model Synthesis Tool: Datapath Formal Verification using CMBC for C Specifications

Ensuring the design of a complex computer chip works as intended – before it is manufactured – is technically and financially critical to semiconductor companies. Exhaustive simulation is impossible, so an alternative method called formal verification is sometimes used. This entails creating a mathematical description of the design and checking the design's correctness against this description by computer-aided mathematical proof. Semiconductor manufacturers use very sophisticated software tools to do this, supplied by Electronic Design Automation ("EDA") companies.

Checking datapath circuits – the parts of the chip that do arithmetic calculations – is extremely critical. A widespread approach to describing the intended function of datapaths is as a software program, written in C with elements of C++. CBMC, a state-of-the art Oxford research tool, offers the ability to process these programs into a form that can be used by the well-established EDA tools that chip designers use.

This project will decisively establish the promise of this technology through a focussed, critical-mass prototyping and at-scale demonstration effort. The aim is to bring datapath formal verification into wide industrial usage, exploiting substantial, pre-existing Oxford research IP as a component.

SECONDMENTS

PI: Daniel Eakins

Department: Engineering

Title: Translation of advanced X-ray radiography techniques for investigating extreme material deformation

This Secondment will use a cutting-edge, time-resolved X-ray radiography method we have recently developed at the European Synchrotron Radiation Facility (ESRF, France) to overcome longstanding challenges in the measurement of material deformation in samples subjected to high-rate and shock loading. Understanding the properties of materials under the extremes of pressure (MPa – TPa), temperature (1000's K) and strain-rate (10^4- 10^7 s^{-1}) induced by shock-compression is profoundly important to the performance of aerospace materials, an appreciation of how planetary bodies are formed through impact, improving explosive mining methods, defence scenarios, and ultimately understanding the fundamentals of mechanical deformation.

This Secondment will allow for the translation and application of the world-class dynamic X-ray radiography method and analytical techniques developed by the Secondee in his EPSRC-AWE iCASE funded PhD (grant number: 1378728) to materials physics problems of interest to AWE. This transfer of knowledge will provide AWE with difficult-to-access data to test and improve their in-house modelling capabilities and sharpen their experimental methods over the course of one year through several experiments, which is a significantly accelerated application of the technique than would be achieved through AWE working as an independent collaborator.

Moreover, the Secondment will provide the Secondee with access to otherwise-unavailable world-class modelling codes and analytical techniques, yielding stronger results for both AWE and the Secondee than could be achieved with either party working alone. This Secondment will also help establish the dynamic radiography method as a permanent fixture at ESRF for industrial and academic users, directly supporting a long-term proposal (LTP) awarded to the PI. Accordingly, it is envisioned that this Secondment can help to increase industrial participation in EPSRC funded research at ESRF, capitalising on a recent boom in the dynamic loading community's interest in emergent X-ray techniques.

PI: Jeroen Begmann

Department: Engineering

Title: Technologies to achieve healthier contact-sport participation

Sport activities play an essential role in keeping the population healthy. Interestingly, some of the biggest and fastest growing sports globally are contact-sports. These sports create significant economic outputs, with the Rugby World Cup 2015 producing £2.3 billion from a single event and American Football being the highest revenue generating professional sports league in the world.

However, there is a great need to ensure that the contact-sport community can safely participate in physical activity. It is well known that the impact endured in contact-sports can lead to traumatic brain injury (TBI),

Long-term disorders have been identified for severe, moderate and even mild TBI, greatly affecting the daily-life of many athletes.

The objective of this project is develop novel technologies that facilitate behavioural changes to achieve healthier sport participation. A smart Mouthguard will be developed to improve injury prevention through continuous monitoring of breathing for quantification of fatigue and physiological-impact.