IN-PART

Showcasing university research for industry collaboration

Issue 4 | May, 2016

IN-FOCUS: INFORMATION & COMMUNICATIONS TECHNOLOGY

INDUSTRY SHIFT

COGNITIVE COMPUTING

Moving past artificial intelligence: computers that reason

IBM Research

CONNECTIVITY

THE INTERNET OF THINGS

Ambient energy harvesting for the new infrastructure

Zepler Institute: University of Southampton

FUTURE MEDIUM

QUANTUM TRANSMISSION

Embedding quantum states with information

The University of Bristol

THE INTERFACE

COMPUTER INTERACTION

Designing enhanced human-computer exchange

City University London

IN-FOCUS

Information & Communications Technology | May, 2016

FEATURING RESEARCH, INNOVATION & COLLABORATION OPPORTUNITIES FROM:

Prifysgol Aberystwyth University
University of Birmingham
University of Bristol
Brunel University London
University of Cambridge enterprise
Cardiff University Prifysgol Caerdydd
City University London
UEA University of East Anglia
University of Essex
University of Huddersfield
University of Leeds
Loughborough University
Northeastern University Center for Research Innovation
OIST
Plymouth University
Princeton University
The Rockefeller University
University of Salford Manchester
University of South Wales Prifysgol De Cymru
University of Strathclyde Glasgow
Swansea University Prifysgol Abertawe
Penn University of Pennsylvania
University of York
Zepler Institute

IN-PART

EDITORIAL

Issue author:
Oliver Hickman, PhD

Copy-editors:
Emma Brown
Rory Galloway
Robin Knight

Design:
Alex Stockham

CONTACTS

Communications:
Alex Stockham
T: +44 (0)20 3286 5945
E: alex@in-part.co.uk

Company Directors:
Patrick Speedie
T: +44 (0)114 360 8074
E: patrick@in-part.co.uk

Robin Knight
T: +44 (0)20 3286 5945
E: robin@in-part.co.uk

IN-PART
Sheffield - London

Registered Office:
Innovation Centre,
217 Portobello Street,
Sheffield, S1 4DP

T: +44 (0)114 360 8074
E: info@in-part.com
W: in-part.com

A NOTE FROM THE EDITOR

Welcome to IN-FOCUS

Inside these pages are the latest technologies from academic institutions committed to industry engagement through their use of IN-PART. The enclosed opportunities are open for commercialisation, co-development, collaboration, or simply knowledge transfer, with industry.

Information and Communications Technology is continuously and positively reinvented; today more than ever before, university innovation is at the forefront of disruption in the sector. The following pages will be of highest value to industry professionals who are keen to drive their companies forward by harnessing this innovation.

Technologies featured in IN-FOCUS emanate from some of the worlds top universities and, importantly, from forward-thinking institutions with the greatest awareness of the importance of collaboration.

Each university technology within this publication is signposted by the following symbol: (). You can find more information by searching for key words, highlighted in the text, using IN-PART.com. It is here that you can view further information about an opportunity and make contact with the associated university via personal introduction from our team.

IN-PART.com is an industry-exclusive collaboration platform featuring curated and existing opportunities that are actively seeking industry interaction. Registration is exclusive to professionals but entirely without cost and can be completed quickly, through the website.

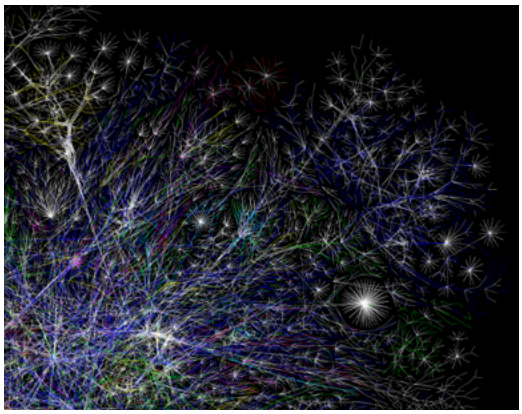
We would like to thank the universities we work with, who represent some of the best in the world, and also the industry contributors within this issue who provide fascinating insights into their commercial worlds' alongside the latest ground-breaking technology.

From everyone at IN-PART, we hope you enjoy reading about the latest technical innovations from universities, and importantly, engaging with those behind them.

Robin Knight, PhD
IN-PART Co-founder

Printed by TBC
Cover image: © mirexon / Fotolia
Contents page Creative Commons image credit: 0) r2hox; 1) Opte Project; 2) Groman123

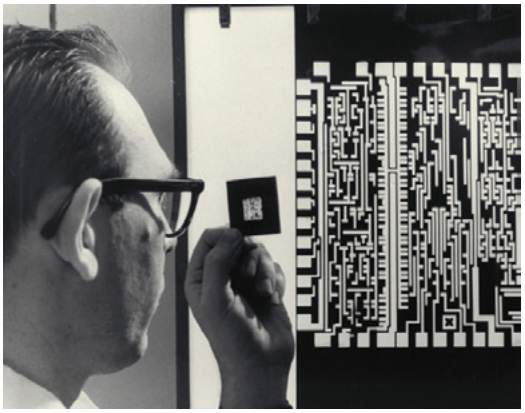
Contents



> Universities possess specialist expertise and fundamental understandings which help untangle the ever-increasing complexity of information.
>
> - IN-PART,
> **Visual & Graphic Processing, p.12**

IN-PART OPPORTUNITIES

= **IN-PART** collaboration opportunity



> Like so many advanced technologies that were conceived before their time, artificial intelligence has come to be widely misunderstood.
>
> - Costas Bekas,
> **IBM Cognitive Computing, p.30**

EDITORIAL FEATURES

Connect with the researchers
through **in-part**.com

Communication Technologies

Only 20 years ago, communications technology was concerned with transmitting information by telephones or fax. Then came mobile phones and the internet, and now we live in cities of millions beneath an umbrella of wireless broadband signals. This is all possible because of huge technological advancements from universities that have changed the way we generate, transmit and receive the signals that connect us to one another.

OPTOELECTRONICS

As we find ourselves in the midst of a biomedical and nanomaterials revolution, never has the field of optoelectronics been so pertinent to continuing the rich tradition of human discovery. Technologies which source, detect and control light - and the other invisible forms of radiation such as gamma rays, X-rays, ultraviolet and infrared - allow us to look beyond and inside ourselves.

In the same way that graphene has revolutionised the fields of nanotechnology and electronics, molybdenum disulfide (MoS_2) 2D films offer similar promise for the next generation of optoelectronics. The major challenge is finding scalable and efficient methods of production. Most research to date, has used bulk MoS2 as a starting material and an exfoliation process to remove layers until a single useful layer remains. Unfortunately, this top down approach is low yield, resulting in flakes typically a few hundred square microns in area. Now, a research team working at the University of Southampton's Zepler Institute has optimized methods for fabrication of large sheets of MoS_2 by chemical vapour deposition, growing the film from the bottom up, at room temperature, in a manner compatible with conventional photolithography.

The range of applications that could utilize MoS_2 runs parallel to those of graphene, such as contact electrodes and circuit interconnects, and extends to photodetectors, electroluminescent, photo-catalysis, flexible transparent electronics *(Figure 1)*, and biosensing devices, making the global market for optimal production techniques similarly vast. The University of Southampton is looking for investment and collaboration to scale and license this novel commercial process for the deposition of MoS_2 over large areas, unlocking the door to the future of electronics.

A tunable laser is a laser source that can have its wavelength adjusted

ANDREW HART / FLICKR

continuously over a specified range. For some applications a wide tuning range is desired, but traditionally tunable lasers have suffered from wavelength mode hopping during the tuning process which can lead to instability. While tunable lasers have proved hugely useful in research settings, their use has yet to extend into industrial systems, due to limitations in their optical tuning designs and internal components.

Scientists at the Wireless & Optoelectronic Research and Innovation Centre at the University of South Wales, has developed an innovative tunable laser based on a novel etalon design, which enables the tuning of wavelength and laser cavity length simultaneously, without the need for complex and inaccurate gratings which lead to wavelength mode hopping and short lifetimes. This upgrade to existing technology has successfully produced a faster, more stable device with eight times the tuning range, while also being more robust and having a vastly extended lifetime suitable for industrial applications.

The applications for this type of device are wide, ranging from biophotonics and microscopy, to more large scale industrial processes such as gas analysis. These include broadband implementation such as in healthcare imaging, medical diagnostics, biosensors, Optical Coherence Tomography, telecoms measurement equipment and industrial inspection, meaning the potential commercial market for this technology is extensive.

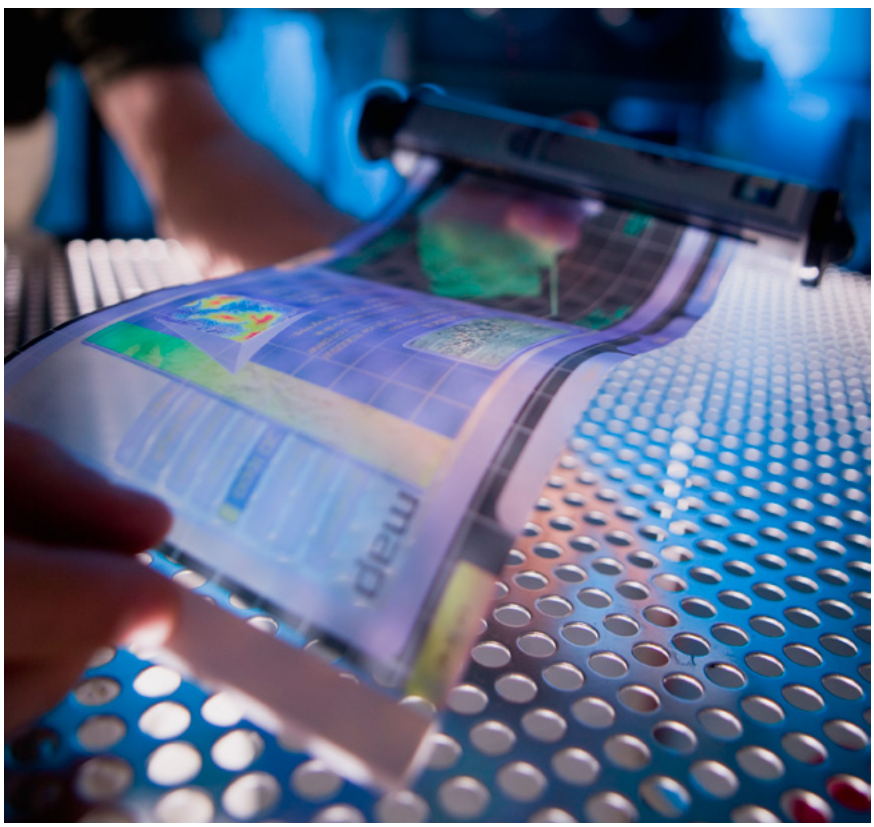
At present the team at South Wales seeks to identify companies interested in licensing and collaborative development of the laser technology for future commercial enterprise.

The ability to generate arbitrary radiation patterns with large-scale phased arrays has long been pursued. Although it is extremely expensive and cumbersome to deploy large-scale radiofrequency phased arrays, optical phased arrays have a unique advantage in that the much shorter optical wavelength holds promise for large-scale integration. Electromagnetic phased arrays at radio frequencies have enabled applications ranging from communications to radar, broadcasting and astronomy, three-dimensional holography and biomedical sciences.

A team working at the Massachusetts Institute of Technology (MIT) have overcome the significant design and structural limitations of the existing technology by producing a large-scale nanophotonic phased array (NPA). This design comprises 64 x 64 optical nanoantennas, densely integrated on a silicon chip within a footprint of less than 600mm². All of the nanoantennas are precisely balanced in power and aligned in phase to generate a specific, sophisticated radiation pattern in the far field.

The NPA, in addition, features active phase tune-ability through dynamic beam steering and shaping with an 8 x 8 array. The featured device incorporates a robust design with state-of-the-art complementary metal-oxide–semiconductor (CMOS) technology, allowing large-scale NPAs to be implemented on compact and inexpensive nanophotonic chips.

Taken together, these features enable arbitrary radiation pattern generation and, in turn, extend the functionalities of phased arrays beyond conventional beam focusing and steering, opening up the possibilities for large-scale nanophotonic devices. The team at MIT seeks commercial interest for exclusive and non-exclusive licensing of the technology which will have applications in a wide variety of fields, ranging from communications to radar, broadcasting and astronomy.



U.S. ARMY RDECOM

FIGURE 1. ***FLEXIBLE OPTOELECTRONIC DISPLAY:*** Developed through an R&D collaboration between the US Army Research Laboratory and Arizona State University, this lightweight screen has been designed to protect the secrecy of a soldiers location, through displaying information without back-lighting.

Antenna phased arrays are one of the most common techniques to perform electronic control of beam direction without the use of any mechanical components. Each radiating element of the array is usually connected to a phase shifter which allows one to modify the phase of the signal between 0º and 360º, with a specific phase step. The phase progression between adjacent elements allows steering of the directional beam to a desired angle.

Linear arrays, in which the various elements are positioned along a single axis, can steer the main beam in 1D, elevation or azimuth. However, when the elements are distributed in two directions on the same plane, the array is considered to be planar, and the main beam can scan in 2D, elevation and azimuth . Existing approaches to achieve 2D systems are expensive, complex, bulky, heavy and have limited performance.

However, researchers at the Wireless & Optoelectronic Research and Innovation Centre (WORIC) at the University of South Wales have developed an innovative technique for novel 2-dimensional transmitarray beam steering using stacked, tunable metamaterials. This system can be easily placed in front of the aperture of an existing antenna, allowing the direction of the main lobe of the radiation pattern of the antenna to be steered in two dimensions.

ECOLE POLYTECHNIQUE UNIVERSITÉ PARIS

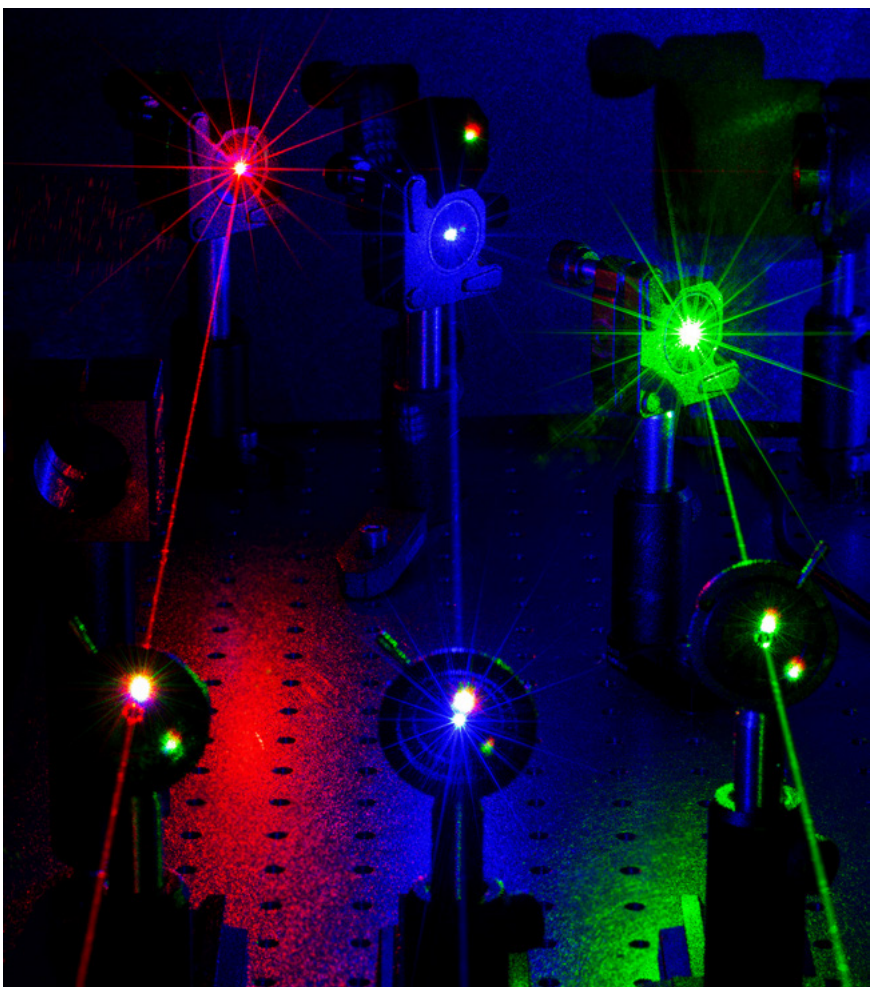


FIGURE 2. ***RGB LASER SYSTEM:*** Scientists globally have been successful in developing systems though which orbital angular momentum states employed to laser beam can be used to transmit information *(see page 25)*.

The device is capable of beam form steering in a fast and efficient manner, without using any mechanical or motorized components, meaning that devices utilising this technology will be low cost, easy-to-build, and benefit from a plug-and-play structure that can be used with any antenna without requiring any re-designing of the existing radio components. The resulting flexibility of the device opens up applications in Point-to-Point and Point-to-Multipoint telecommunications backhaul; including antenna beam alignment due to pole swaying and twisting in the wind, wireless backhaul-links, auto-alignment, and high-directive and fixed commutative beam in specific directions, opening up potentially global commercial opportunities in telecommunication infrastructure.

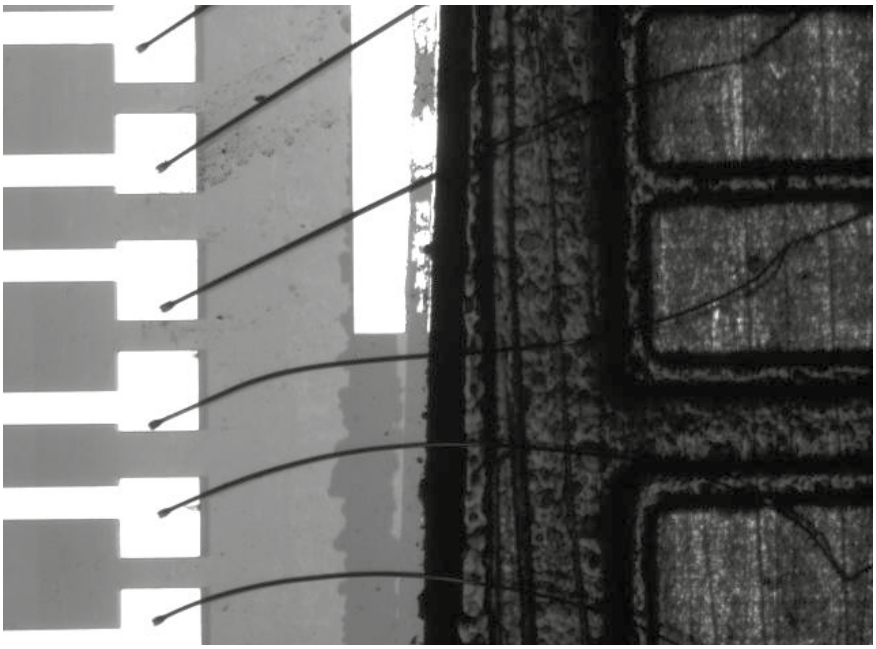
At present, the theoretical concept underpinning this technology has been proven - with patent filed - and the structure is now in a prototype stage. The University of South Wales is seeking commercial partners for licensing and collaboration for the development of the technology.

Lasers *(Figure 2)* are an integral part of many devices, including DVD, Blu-ray players, and many varieties of sensory apparatus, as well as numerous technically specific industrial applications. Nonlinear materials are an integral component of laser light sources, and an exciting area of technological innovation. Frequently they are used to modify or enhance the properties of incoming light. Second harmonic generation is used to generate new light sources at double the frequency of the incoming light, and currently there are no frequencies available for a convenient laser source from this process.

Critically, advances in frequency doubling devices have, to date, failed to significantly enhance the intensity of the second harmonic, which is critical to improving the power, versatility and performance of laser devices. Now, a tunable laser frequency doubling device based around a resonant cavity device has

been developed by researchers at the University of Pennsylvania (UPenn). This innovation enhances the intensity of the second harmonic by more than 3,300 times (as compared to a monolayer on a glass substrate). The device consists of an adjustable resonant cavity that can change its shape via an electrostatically-tunable membrane. The cavity size is tuned until both the fundamental wave and the second harmonic are both in resonance simultaneously, resulting in enhanced output. Because the device is tunable, it can be used to enhance light at a variety of wavelengths.

This novel technology results in a versatile high intensity laser source for use in a range of photonic and optical devices. Currently, the team at UPenn have a functioning prototype system and a filed patent, and are seeking investment and partnership for further development and licensing.



NICOLA SAP DE MITRI

FIGURE 3. ***NANOSCALE COMMUNICATION:*** µm-wide gold pads on a crystal microchip (left), connected by gold wires to a printed circuit board (right). Following Moore's law, components keep on shrinking *(See NEMS, Box 1).*

ELECTRONICS

It's fair to assume that when Joseph Thompson discovered the electron in 1897, he wasn't fully aware of its potential. Now we have a global civilisation dependent on electronics: an arena of technologies that produce, carry and manipulate electron currents. Every facet of our lives is permeated by electronic devices, and here we highlight a number of new university-developed technologies set to expand this exciting field even further.

For industrial energy production and usage, kilowatt power levels are required, attainable by the use of extremely efficient high-power converters. Converters such as these necessitate the use of the latest generation of silicon carbide and gallium nitride. However, the use of these materials presents challenges not encountered with traditional silicon insulated, gate bipolar transistor (IGBT) and silicon diode technology.

To address the challenge surrounding power conversion at this level, a research team at the University of Bristol has been developing new high efficiency power converters. These novel power solutions will operate in the 500W to 3kW+ range, with a predicted final working efficiency of 99.3%. At present, both single-phase and three-phase converters have been prototyped to approximate Technology Readiness Levels (TRL) of 3-4.

These solutions are all fan-less, and require minimal heat sinking. They are compact and lightweight with a mass of 330g and PCB footprint of just over 100mm2. The team is looking for on-going projects and collaborative partners in industry to drive this potentially lucrative and environmentally beneficial technology towards applications in aerospace power conversion, renewable energy and high-efficiency industrial machine drives.

A multitude of electronic devices, such as transistors, rely on the latest developments in semiconductor materials and technologies, especially where there is a need to efficiently analyse and measure electron spin polarization. To this end, researchers at the University of Plymouth have built on our ability to measure Tunnelling Magneto-Resistance (TMR) between a ferromagnetic material and a superconductor, developing a method for the detection and measurement of spin polarized carriers in semiconductors.

In this new technique, measuring the TMR between the ferromagnetic material and the subject material provides a measure of the tunnelling resistance of carriers . This enables measurement of the TMR when the Spin Hall Effect (SHE) is generated in the subject material, allowing the extent of spin polarization within test semiconductor materials to be determined.

When applied, the SHE exhibited by and within a subject material can be analysed, determined and quantified. The research team is currently seeking opportunities to license this patented method.

Nano-scale electromechanical switches *(Box 1; Figure 3)* have emerged as a promising alternative to complementary metal-oxide semiconductor (CMOS) switching transistor technology. These switches exhibit a large on-off current ratio, near-zero off state leakage current, and efficient operation. However,

the required actuation voltage for the current NEM switches is large. Moreover, these switches have low operational reliability due to the effect of static friction that results in frequent irreversible adhesion between the switch terminals.

Recently, researchers at MIT have produced a series of nanoscale electromechanical switches which eliminate the effect of the static friction on the NEM switch. By incorporating a non-conducting, deformable spring-like molecular layer between the switch terminals, they are able to increase reliability. Furthermore, by increasing the stiffness of this spring-like layer they have lowered the required actuation voltage to levels appropriate for CMOS applications.

Instead of using direct contact between the switch terminals as the mechanism for the current conduction, the invention uses tunnelling currents that dramatically increase the magnitude between the on and off states of the switch. The switch can be easily fabricated in a variety of structural shapes and orientations based on the necessity of the end application.

The many benefits of these highly efficient nanoscale switches include: a small footprint, low power requirements, reduced current leakage, ease of manufacture, and a vastly superior transconductance relative to existing semiconductor transistors. The researchers envisage a wide range of applications from standard CMOS-featuring electronics, to a range of precision medical sensors and audio technologies. Currently the team are seeking opportunities for exclusive and non-exclusive licensing of the technology.

BOX 1 : NANOELECTROMECHANICAL SYSTEMS

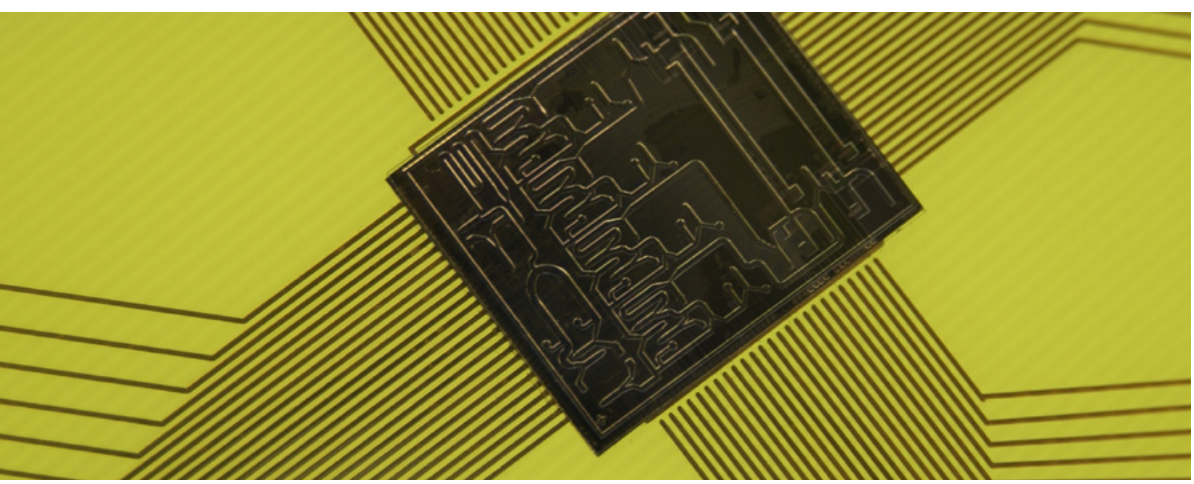
Nanoelectromechanical systems are devices which integrate electrical components with mechanical functionality, typically at the nanometre range of size. They are most often formed of transistor-like nanoelectronics with various mechanical parts, making them especially apt for use as physical, biological, and chemical sensors, such as accelerometers or detectors of chemical substances in air or water. Recent technological developments - especially in the manufacture of carbon-based materials such as diamond, carbon nanotubes and graphene - have been hugely important for the recent improvements in nanoelectromechanical systems.

Nanoelectromechanical systems (NEMS) are devices that integrate electrical and mechanical functionality on the nanoscale *(see Box 1)*. These type of devices are increasingly seen as the next miniaturization step from microelectromechanical systems. NEMS can be used for a variety of applications, including chemical and physical, as well as bio-sensor technology, to RF communications and accelerometers.

Existing NEMS sensor systems, which have typically used thick, heavy, top metal electrodes, have proved limited in overall performance due to low sensitivity, range, and speed of detection. In response to the increasing demands for nanoscale technologies that can integrate electromechanical systems, researchers at Northeastern University have developed a patented technology for next generation NEMS devices, utilised for sensor and communication systems.

Their technology overcomes existing limitations of NEMS devices through the novel use of ultra-low mass, 2-dimensional electrically conductive graphene material. Incorporating graphene into the top electrode results in dramatically increased performance, with vastly superior sensitivity, limit of detection and speed in sensor applications, as well as increased performance in RF communications. In addition, the use of graphene greatly reduces the mass and volume of devices, and combined with extremely thin and light conductive electrodes, the team have produced electrical conductivity comparable to gold electrodes 100 times thicker.

This technology will allow for advanced, ultra-sensitive and fast NEMS. The team at Northeastern seek interaction with industry for



MEMS: Lab-on-a-chip devices enable nanoscale sensing *(National Human Genome Institute)*

exclusive and non-exclusive licensing of the technology, as well as for potential partnership in its continued developmental.

Within the field of optics, a heterojunction is a crystalline interface between two layers of dissimilar crystalline semiconductors. Heterojunctions are required in numerous optical devices, such as lasers, bipolar transistors and field current transistors. The current process for manufacturing heterojunctions is complex, costly, and uses environmentally damaging material to produce an unsafe and frequently impure product.

As a solution to this problem, researchers at the University of Birmingham have developed a small molecule compatibiliser for organic electronic applications, resulting in a novel, environmentally friendly approach to the fabrication of perfect heterojunctions.

Specifically this involves the blending of incompatible organic compounds in an isotropic melt, followed by cooling, and results in separation of the compounds and the assembly of a perfect heterojunction. The process can be finely controlled, and the phase dynamics tuned by varying the amount of small molecule compatibiliser. Importantly, this novel production method removes the requirement for organic solvents, and results in superior quality without non-active additives which could contaminate the final product.

This technology has the potential to revolutionise the fabrication of perfect bulk heterojunctions for organic solar cells and LEDs, and has a range of applications in other optoelectronic devices. The researchers seek industry collaborators for developing their proof of concept technology into an effective product. Alternatively, there may be opportunities to fund a spin-off company to develop and market the technology.

Many technologies, from smart phones and laptops to smart cars, require small portable sources of power. While the portable fuel cell market is in its infancy, its growth is largely limited by the technology solutions currently available. In theory, micro-solid oxide fuel cells (micro-SOFCs) have the highest specific energy per unit mass and much faster recharging times compared to other portable power systems being researched today. However, they are currently limited by their high operation temperature.

A research team at Cambridge University has developed a unique thin-film electrolyte for low temperature micro-solid oxide fuel cells. Epitaxially grown at the nanometre scale, their electrolyte provides two orders of magnitude improvement in ionic conductivity compared with current solutions on the market, enabling a reduction in operating temperature to ~300°C. In addition to improved ionic conductivity, this electrolyte exhibits minimal heat loss and short-circuiting, as well as simple fabrication.

At present, the Cambridge researchers do not have the in-house capabilities to build a cell to prove that the observed electrolyte performance in-practice leads to the expected overall cell output. Collaborators with thin-film expertise and knowledge of micro-SOFC systems are sought to build and evaluate a test cell.

TELECOMMUNICATIONS

Broadband signals, that allow us to access the internet, are transmitted across a specific locale by carefully arranged antennas. The technology that allows this, 'broadband smart antenna beam-formers', requires adaptive delay of very wideband radio frequency (RF), and the processing of complex digital signals. This is at present made difficult by the limited bandwidth of analogue-to-digital converters.

As a solution, researchers at the University of South Wales have developed a smart photonic, high bandwidth, directional, multi-beam antenna. This antenna significantly increases reception accuracy and enables many wireless users to operate within the same frequency band. This in turn allows increased capacity within a band of radio spectrum and therefore increased coverage without causing interference between users. The broadband feature of the antenna and data transmission rate, coupled with the high sensitivity

MAST ARRAY: Antennas on a hill in LA constantly transmit & receive information *(Andrew Hart)*

beam steering, will revolutionise several highly lucrative market arenas, including wireless metropolitan area networking using WiMax, or high speed localised wireless data transmission for medical and security applications. Through collaborative research and development, this technology will enable a broadband, electromagnetic-interference-free, compact, low weight, motion-free, multi-element antenna, or smart antenna, to outperform all competing technologies on the market.

The use of broadband has grown in pace with our use of smart phones and tablets, and the increasing demand for high data speeds and fast, reliable connections is putting unprecedented pressure on mobile network infrastructures. Mobile network operators require a cost effective way to handle this ever-growing demand and support the adoption of next generation mobile phone systems. Conventional outdoor macrocell networks that provide coverage from large, high-power base stations struggle to meet the growing demands.

It is believed that a new approach should deploy urban, small cells, known as metrocells, which offer mobile network operators a cost effective solution, but require careful planning. Mobile operators use radio planning tools to determine the ideal location, configuration and parameters for base stations. However, as mobile cells get smaller in size, for the move to metrocells, particularly for 4G LTE applications, the terrain and environment must be considered in planning calculations, optimised specifically for of metrocells.

Researchers at the Wireless & Optoelectronic Research and Innovation Centre at the University of South Wales have developed and validated an analytical model which provides a significantly improved, efficient planning and design tool for Point-to-Point and Point-to-Multipoint high speed radio links.

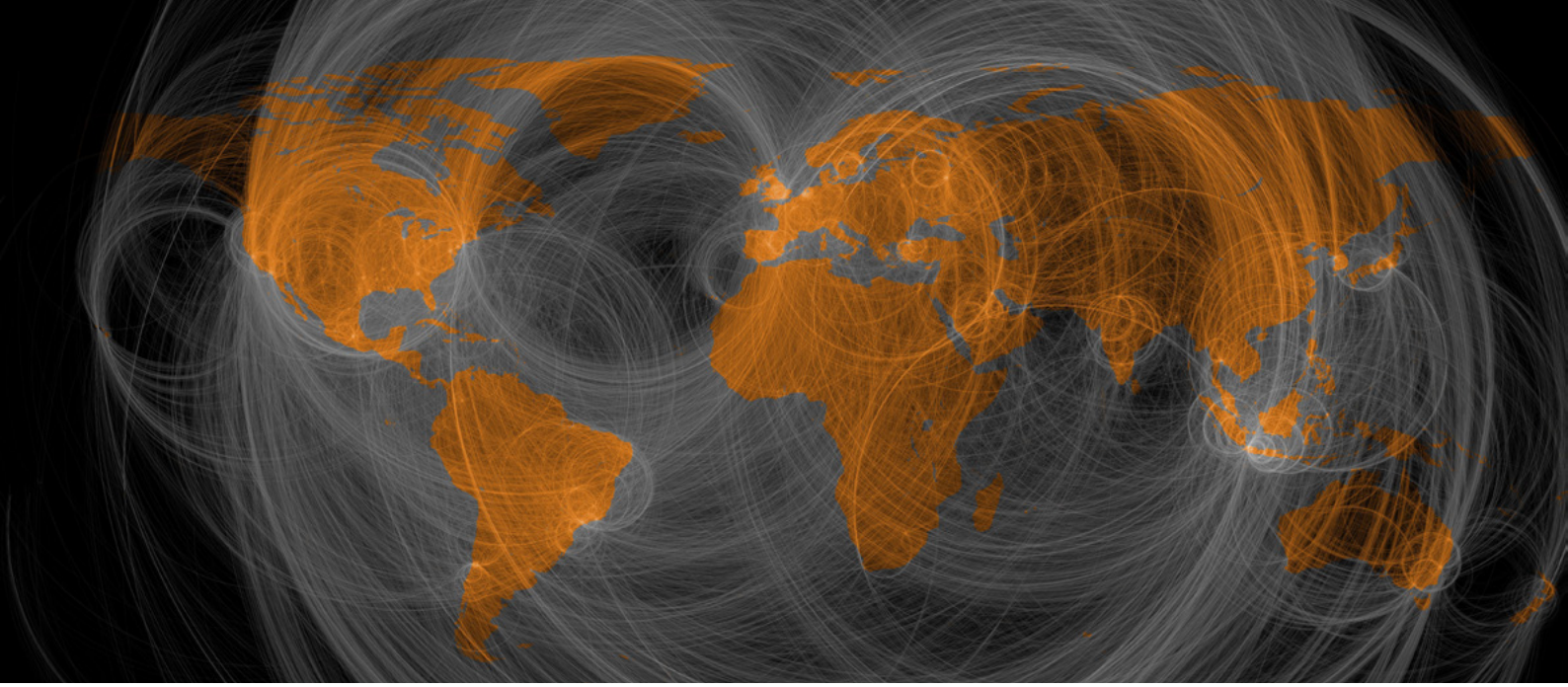
This innovative mobile network 3D radio frequency planning tool would be integrated within a 3D electromagnetic simulation platform for microwave, radio frequency and telecommunication applications. The technology would provide deterministic radio and channel propagation modelling, resulting in the ability to automatically process hi-res 3D terrain and clutter data, enabling faster, more accurate and efficient planning that doesn't require calibration or tuning. Likewise, this tool can also be integrated into existing planning software. The team at USW seeks licensing opportunities for the technology and source code partnerships for further development and commercialisation.

Optical fibre is a critical component that currently underpins the Internet and most modern communications - transmitting data in a range of formats at increasing speeds. Inside any given optical fibre there are many different optical wavelengths being transmitted, each carrying unique information. The fibre's capacity to transmit information is increased by increasing the speed of transmission or by putting more optical wavelengths down the fibre, or both. Over long distances (long-haul), this is straightforward. However, when the fibre reaches, for example, the edge of a city, then there is a need to separate and route the information to many different locations.

A team at the University of South Wales' WORIC has developed a new all-optical wavelength conversion (AOWC) technology that allows all-optical wavelength conversion with the advantages of high bandwidth, high speed and low power consumption. This technology is set to enable delivery of high-performance, network-based applications, and will support next generation 'all-optical' networks, representing a step change for the telecommunications industry and its users.

The benefits of this innovation over current AOWC technologies are multiple, two of which include the ability to select wavelengths for data transmission, and data transmission and wavelength conversion that does not affect transmission speed, allowing significant improvements in the quality of service. A patent has been filed and the researchers are seeking companies for licensing and co-development partnerships.

CITYSCAPE: Modern cities require 3D radio-frequency mapping to optimise mobile networks *(Magnus Larrson)*



ERIC FISCHER / FLICKR

Information & Computing Technologies

As our world grows ever more connected, we increasingly depend on the devices and apps that empower our lives. Whether it's for social networking, or highly technical data analysis, we rely on a widening array of tools to generate, manipulate, present and exchange data between one another. Here, we examine some of the most exciting university developments being made in the world of information technology.

INFORMATION & DATA PROCESSING

Search functions can sometimes be inefficient. Simply using the wrong keyword can result in critical results being omitted. There are often related keywords which could dramatically improve search results... but they aren't always immediately obvious.

Now a team of researchers at the University of York has designed a platform for discovering unknown connections in data. This new search approach helps users find the unknown connections within large databases of information. It uses two or more sets of keywords to identify database entries containing these keywords and identify intelligent relationships to other database entries.

The platform intelligently links database entries with previously unknown information which joins the two search terms to be discovered. This provides an effective tool for linking current data repositories with external repositories or archived data.

66% of people asked rated the platform better than Google, with 73% having greater confidence in the results. Having successfully deployed this intelligent and cost-saving search facility within the Professional Services industry, the team is now looking for partnerships with companies specialising in large databases or enterprise systems to extend this platform to other industries.

Driven by the increasing need for accessibility of information, huge efforts are being made by libraries, document repositories and commercial organisations to digitize printed documents. This usually occurs through a computationally-intense process of image analysis termed Optical Character Recognition. To enhance the speed and accuracy of this process, a 'ground truth' template can be generated. This template refers to crucial information on, for example, document layout, reading order, or images from text.

Now, researchers in the Pattern Recognition and Image Analysis Research Lab (PRImA) at the University of Salford, have developed advanced software capable of automatically generating 'ground truth' data for digitized documents. Data generated by Alethia: enhanced optical character recognition software is used to inform the digitization and optical character recognition (OCR) step to significantly improve the speed and accuracy of the process. Alethia can be used by organizations to test and evaluate the effectiveness of the many different types of OCR software currently available for their specific application. Hence, in addition to licensing software, there is also the potential for a service-based opportunity if appropriate.

This software has enormous potential for use in libraries and other public sector document repositories with a requirement to digitize large volumes of text or, with commercial agencies, such as family history providers. There is also a market to be exploited in helping providers of commercial OCR packages improve their own software. Alethia is more sophisticated than existing tools, offering increased support for complex document layouts, extensive compatibility, and a slick, user-friendly interface. Researchers at PRImA are looking for industrial backing and collaboration to develop, license and take the software to market.

When different computers or mobile phones communicate over wireless ad-hoc networks, the conditions are always changing and devices are constantly entering and leaving networks. This generates numerous problems for network engineers, including dispersion, where the messages get spread out over time due to the physical limitations of the medium they are travelling through, and collisions, where multiple devices send messages at the same time. In addition, data transmitted across a network is liable to become corrupted.

To address these problems, researchers from the University of Bristol has devised a communication system for ad-hoc networks in dispersive channels. Their unique 'Channel Signature Modulation' is a communication system for ad-hoc networks, especially those featuring communicating nodes operating in highly dispersive environments.

The novelty of this technology lies in using channel signatures to specifically construct communication waveforms *(Box 2)*, changing the way information is encoded. This turns dispersive communication channels into an advantage, allowing all users of the network to transmit and receive signals at the same frequency and in the same time slot, without equalization, rake receivers, cyclic Prefix, or any complicated Media Access Control layer coordination.

The applications for this technology are extensive, ranging from wireless ad-hoc networks, vehicular and optical communication networks, power line communications, and underwater networks. With US and UK patents pending, the team is seeking industrial partners and companies interested in licensing this technology.

As the range of utilities supported by electronic devices grows, so too will the demands on their ability to process data. Individual devices, such as phone and tablets, are limited by their data processing power. To process more data, more sophisticated algorithms are necessary which requires greater power. Current system methods require high system resources in terms of integrated circuits and a larger silicon area.

Researchers at the University of Huddersfield have developed a novel approach to improve data processing power by demodulating signal phase data, which changes the speed and cost of data processing. Using cross correlation to replace the traditional 'tan' function requires less circuitry, resulting in vastly superior performance, with significant cost reduction and overall system size.

This novel system demonstrates a 20% increase in system performance whilst simultaneously reducing costs and chip resources by 80%. The creators envisage the potential application of this technology by 'set-top box' manufacturers (digital TV), as well as within m-health, e-health, and computer game markets. While currently at technology readiness level 3, the team is seeking industry collaborators or co-development partners to develop a prototype.

BOX 2 : WAVEFORM COMMUNICATIONS

All digital communications require that abstract digital data is converted into analogue signals for the purpose of transmission. Data is transmitted in the form of electromagnetic radiation, usually in the radio or microwave regions of the spectrum. However, this spectrum has a limited frequency range, and at different parts of the spectrum, the transmitted waves interact differently with the environment. Developments in waveform communications attempt to maximise effective use of the electromagnetic spectrum for communicating diverse information in myriad environments.

VISUAL & GRAPHIC PROCESSING

Now more than ever we communicate our experiences in real time by uploading photographs, and other digital images, using our smartphones. With so much of our lives now presented in this visual manner, technology has to keep providing us with new ways to produce, modulate, and present images.

For example, tremendous progress has been made in recent years to improve the speed and resolution of image generation. But one unmet goal remains: the ability to automate our analyses of images and the information contained within. To optimize the

R2HOX

LOST IN DATA: Universities possess specialist expertise and fundamental understandings which help untangle the ever-increasing complexity of information.

automation of data capture from static images, both hardware and software challenges persist.

In a significant move towards the goal of increasing automated image analysis, a team at the University of Aberystwyth has developed software for texture-based segmentation and identification of texture connectivity. Their technology identifies the connectivity of texture types represented in digital images, which provides improved results through more detailed modelling in higher dimensional spaces.

In particular, this software has potential in numerous lucrative sectors, especially within the medical imaging sector, for magnetic resonance imaging. It could be readily extended into the manufacturing industry, or even surveillance systems for the analysis of photographic imagery. Currently protected by two patents for the methodology, the team seeks partners interested in potential applications, development opportunities and licensing of this technology.

Recent years have seen an influx of visual sensors to the market, in applications such as security surveillance, healthcare and ambient assisted living. These sensors aim to capture human behaviour and produce a customisable summary from the recorded video. This summary would ideally be searchable in natural language, similar to searching through a text document: in a sense, converting images into text-based data.

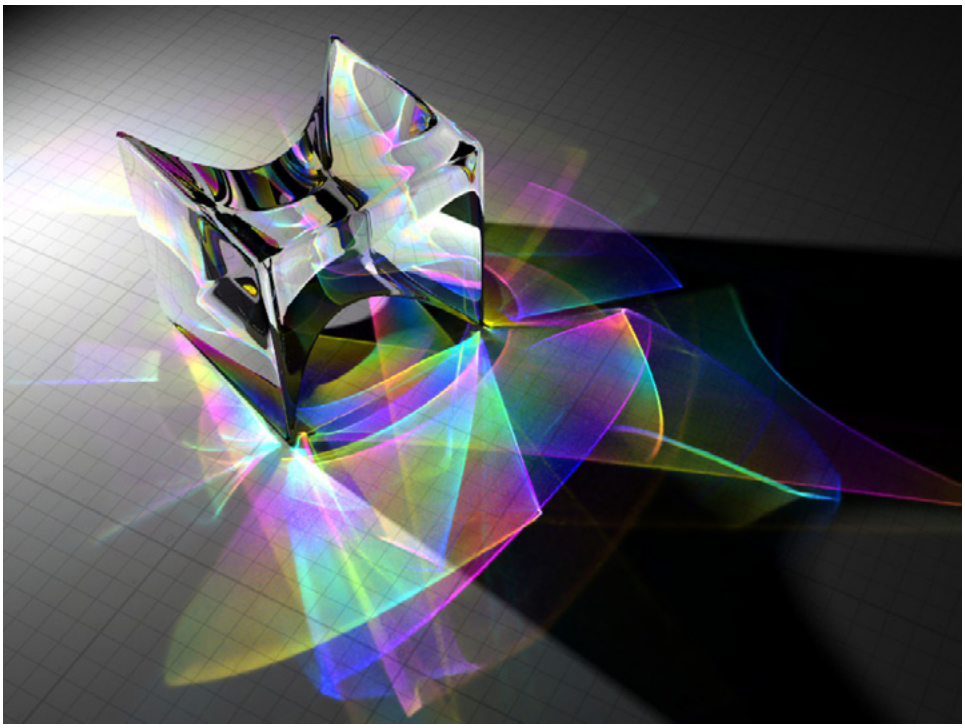
However, the effectiveness of this type of technology is invariably limited by the difficulty of detecting specific human behaviours using visual sensors and summarizing this in real time. This limitation is partly due to the massive data sizes of the images being interrogated, and partly due to the high level of uncertainties associated with human behaviour.

A team of researchers at the University of Essex has developed a robust behaviour recognition system for video linguistic summarization. This machine vision-based event detection and summarization using type 2 fuzzy logic control system uses the latest model of the 3D Kinect camera. This camera is optimised by the Big Bang Big Crunch algorithm to obtain the parameters of the membership functions and rule base. The proposed technology outperforms existing systems; it's performance increases as the number of observed subjects increases. The output of system activity, together with relevant event descriptions (video data, timestamp, location and user identification) can be efficiently summarized and stored in a back-end structured query language event database.

The system is applicable to detecting multiple behaviours and demonstrates a range of benefits over existing systems, including increased performance in higher uncertainty situations such as multiple people in a video frame or occlusion than competing type 1 fuzzy logic system or non-fuzzy systems. The device is non-intrusive unlike many wearable device solutions, and it can be used for generating automatic alerts or for searching occurrences at a later time.

The system's searchable output technology and activity retrieval and high-definition video playback capability make it highly applicable in security surveillance, healthcare, ambient assisted living, with extensive and lucrative market potential. The researchers are seeking opportunities for non-exclusive licensing.

FIGURE 4.
REALISTIC REFLECTION:
Crisp, complex refractions of light though a transparent optical element, constructed by the University of Swansea's 'Photon Relaxation' technology.



An area driving the field in image processing technology is animated cinema. Animated cinema has collaborated with the gaming industry to bring us ever more convincing 3D animated images, with life-like movements and exquisite detailing. One of the most computationally-intensive processes in producing successful graphical displays of data is caused by ray tracing. This is when the intersection between a line of sight (or light source) and a 3D surface (represented by a large database of triangles) is calculated.

Key to the generation of realistic 3D images in films or game is the ability to photon map an environment. Photon mapping requires reconstruction of the lighting using virtual photons in a computer-generated image.

Using traditional approaches, there has been a trade-off between reducing variance, which produces noisy images, and bias, which leads to blurriness. This can be mitigated by using an order-of-magnitude more photons, but not without increasing the time required to reconstruct the light, and ultimately the same trade-off remains.

Now, researchers from the University of Swansea have introduced 'photon relaxation' - a method which improves the realism of light distribution in virtual reality *(Figure 4)*. This method addresses the problem of bias-variance trade-off with a new algorithm, which repositions the photon as a function of its proximity to its nearest neighbours.

Repositioning judges the size and direction of positional error based on where the photons are located. The algorithm combines point relaxation processes with feature detection that analyses the photon distribution of a graphic and isolates points which lie near edges, boundaries and other important visual cues. This keeps the graphics generated crisp, and produces dramatically more realistic images with fewer photons in the estimate. This speeds up rendering time, greatly reduces blurring and noise, and reduces memory overhead.

Given the marked reduction in processing power, time, and memory, this novel system will appeal to relevant markets that will ultimately benefit from this innovation; including all digital rendering applications, especially the production of computer animated films and development of games, It will also extend to architecture applications. With a patent filed, the team is looking for investment and collaboration to take this technology to market.

When rendering images in real time, such as in computer games, the computational requirements are so great that only primary ray tracing is performed. Due to these limitations, use of global illumination and multiple reflections is often reserved for high resolution movie quality, as each image can take hours to render. Furthermore, the more dynamic the image, the more computationally intensive it will be.

A lower level of memory usage is highly advantageous to the computer systems that create 3D graphics as internal memory storage is limited and of critical importance. To increase the power of modern rendering techniques, a team of researchers at the University of Swansea has developed a graphics accelerator for ray tracing. This technology significantly increases the efficiency of intersection identification, allowing

FIGURE 5.
GLOBAL ILLUMINATION:
A ray tracing accelerator, from the University of Swansea's makes feasible for animation rapid tracing, global illumination, and multiple reflection calculations.

the production of movie quality graphical presentation for real-time rendered images. In addition, the software allows exact memory requirements to be defined, while being much faster and less power hungry, making it desirable for mobile applications on smartphones and tablets. The algorithm is available as a library in a format compatible with current OpenGL or DirectX software and is suitable for committing to hardware as a graphics accelerator.

This newly patented software process also promises to allow for the production of real-time 3D images for scenes in computer games and films that are comparable in quality to that of static 3D images. The researchers are interested in an industry collaboration to develop the software for applications including 3D games, films and architecture.

The Fourier Transform (in this case, the 2D Fourier Transform) is a mathematical procedure used in computer-generated imagery. The ability to perform these 2D Fast Fourier Transforms of data are now recognised to be a computational constraint for real-time or near real-time imaging systems. FFTs inherently assume that image edges are periodic, leading to high amplitude "cross-shaped" artefacts in the Fourier domain. These artefacts can be propagated to later stages of processing, adversely affecting decision critical applications, such as in medical diagnostics.

A team at the Okinawa Institute of Science and Technology has developed a technique for 2D Fast Fourier Transforms with simultaneous edge artefact removal. The ability to perform 2D FFT simultaneously with edge artefact removal decomposes the image into periodic and smooth components in real time, which improves the capacity for high speed industrial tracking.

This technique will find numerous applications within medical diagnostics such as MRI and CT scanners, and research-based applications such as electron microscopy and astronomical imaging. Furthermore the system can be easily integrated into industrial applications as it uses the industry standard PCI Extension for Industry express (PXIe) interface. The team currently seek partners to license this patented technology.

SOFTWARE, MODELLING & APPS

Software can be designed for almost any purpose as algorithms can be written to interrogate any type of data. This allows us to build software that generates user friendly output that can help us understand and interpret huge datasets, and produce models of real world situations based on a fixed number of factors and variables.

Such tools can be hugely beneficial in modelling systems such as environmental change, biological interactions, economics, and business. However, economic models used in health applications can be cumbersome and time consuming.

To resolve this, Researchers at the University of East Anglia have developed a novel modelling platform for performing economic evaluations of new pharmaceuticals, devices and other health technologies. This web-based modelling platform not only increases the accuracy and speed of running economic models but also reduces the time taken to prepare and assemble models from weeks to just a few hours. The system enables users to test more quickly and accurately

many more potential scenarios than existing techniques to optimise cost-effective solutions. All data outputs are available in real time, and assumptions can be interrogated iteratively and models updated as new data becomes available.

The method has been fully tested against established techniques and has shown a high degree of agreement with no statistical difference detected. Importantly the novel modelling platform can execute these results in less than a ten thousandth of their times. The designers are interested in continued development of the platform with collaborative partners.

Another domain in which good software design can deliver meaningful improvements is in planning. In situations such as healthcare planning and organisation, in which networks are vast and complex, having the correct platform to input, search and analyse data is vital for efficient functioning and planning.

For example, current methods of recruitment into clinical trials rely on ad-hoc engagement through adverts and word of mouth. Paper-based systems employed by staff in planning and recruitment mean that knowledge of clinical trials amongst healthcare workers is poor, and dissemination of information - especially the inclusion/exclusion criteria - is therefore inefficient. Overall this results in poor patient recruitment and hence low financial returns.

A team working at Cardiff University has developed myTrial: mobile software solutions for clinical trial recruitment. myTrial is supported by a powerful automated online database, which presents key trial information in a structured and searchable format. This includes inclusion/exclusion criteria, distance from the user's current location, and contact information for active trials. Additional analytics built into the software generate data of value to clinical trial sponsors and organisers.

This software promises to increase recruitment rates into clinical trials, facilitating the generation of more reliable down-stream results. It will also increase income to NHS Trusts from recruitment into clinical trials. Improved, more up-to-date access to clinical trials information for front-line clinical staff, will help to identify and address reasons for poor recruitment into a given trial and reduce costs for pharmaceutical sponsors.

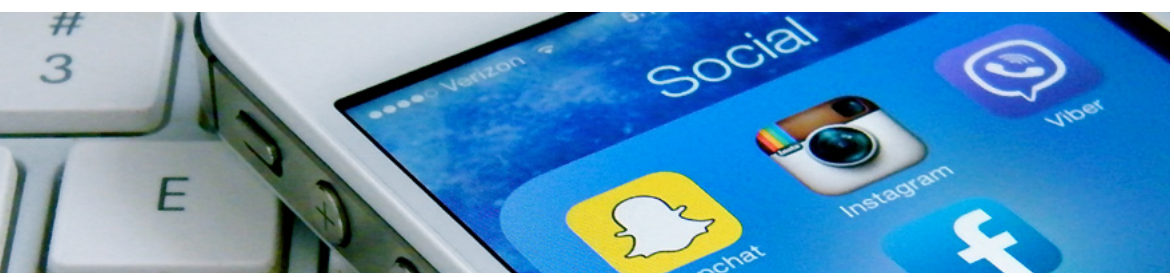
myTrial is currently available on a website (www.myTrialapp.com) and as an iOS mobile app which has been successfully tested on iPads at two pilot sites through the University Hospital of Wales, Cardiff. The team look for support and collaboration in expanding the suite for use nationwide and internationally.

The ability for people to express and exchange their opinions and feelings has increased beyond all expectations in the past ten years of internet expansion. Social networking platforms such as Facebook and Twitter are only a part of an increasingly integrated online nexus through which people communicate in every way imaginable. To the military and national security agencies this has delivered enormous challenges as people are now able to securely exchange information beyond the reach of state surveillance technologies. In contrast, however, opportunities have emerged to rapidly detect and survey discontent and uncover oppositional movements.

Recent urban disturbances such as the fast-moving riots of 2011 in London have illustrated the key role played by social networks in orchestrating dissenting activity. The challenges have since escalated due to the sheer number of platforms through which social interaction and public communication operate.

To counter the threat posed by the opacity of public communication through these networks, researchers at Loughborough University have devised 'EMOTIVE: extracting the meaning of terse information in a geo-visualisation of emotion'. This system comprises a rule-based linguistic database which can be trained to recognise sensitive words and phrases and make semantic links between them, while delivering specific descriptors to the analysts. Email, social networks, microblogs, and webpage comment sections will be selectively monitored. The software is equipped to deal with sparse, grammatically incorrect, and informal prose. While defence and national agencies already have experience monitoring these data sources, this novel tool adds an extra filter of analysis that will work in near real time to amalgamate data from several sources.

The EMOTIVE engine has a number of applications in fields such as marketing, social media and law enforcement. It can be built into existing software packages and platforms to produce anything from a simple app to a stand-alone reporting suite. The EMOTIVE team are seeking companies interested in licensing the software and would like to work with collaborators to develop the system for additional end-stage platforms.



SOCIAL MEDIA: Information can be geographically mined from social networks. *(magicatwork)*

CESAR QUINTERO / UNSPLASH

Digital Media & Audio Technologies

From 3D cinema and interactive billboards, to voice recognition software and the resurrection of popstars, the way we experience sights and sounds is constantly evolving through R&D taking place in universities. Here we explore a selection of university-developed digital media and audio technologies, which through industry collaboration, are set to change the world.

INNOVATION IN DIGITAL MEDIA

The success of online networks such as Vine is a clear testament to the simple power of video and audio in communicating ideas. For years, the technology that allows us to capture audio and visual footage has been rapidly progressing. Now we all have pocket-sized devices that allow us to record and manipulate visual and audio data. But, with so much video and audio data being exchanged, we face new challenges in creating the technology to manage it.

Key to any device used to record video footage is the lens. Standard rectilinear lenses of normal videos and images can only achieve a view angle of up to 90-100 degrees, while videos and images taken with fisheye lenses have a wide view angle of up to 180 degrees. The benefit of the wide view angle of fisheye lenses is comprised, however, by significant barrel distortions. This results in visibly misshapen human faces and curved straight lines as objects move during a video sequence. The distinctive curvilinear perspective generated by fisheye lenses may be desirable in still photography; but in videos the resulting distortion renders them hard to understand, uncomfortable to watch and diminishes the overall continuity of the footage.

Engineers at Swansea University have developed an efficient and robust fisheye video correction pattern using per frame transformations which minimises time-delaying distortions while maintaining continuity of objects' movements in films. To obtain natural looking results, a number of distinct but related correction criteria are used to remove visual distortion such as straight line distortion, boundary consistency, orientation consistency, local shape similarity, homogeneity and chronological coherence. It also introduces automatically-generated continuous and compatible correction constraints for individual video frames and presents a feasible

implementation based on video tracking with a mechanism of adaptive error detection and correction. The input video is corrected by a method of streaming that works on a frame by frame basis.

The potential use of this new technique is extensive, with obvious applications in mobile phone software, and additional uses in surveillance monitoring, machine vision and biomedical scanning systems. With this technology, continuous video is comparable in visual quality to photographs produced by state-of-the-art fisheye still photography cameras. The researchers are looking for investment and collaboration to further develop and monetise this technology.

It is not just visual light that can be used to record video footage. The technology that allows the recording of images generated in the infra-red area of the spectrum has been around for decades. However, the vast majority of thermal imaging devices use a mechanical shutter which periodically blocks incoming signals to correct the response of the elements with respect to the background. Despite an apparent simplicity, this technology is based on moving parts, which restricts applications of thermal imaging for high-speed measurements and in environments with high g-forces. In addition, mechanical shutters are bulky, requiring space to accommodate the blade, and energy inefficient.

Using electro-optical modulation is an attractive alternative as it simplifies operation, provides significantly higher modulation speed, shrinks dimensions, is resistant to mechanical shocks and is silent. A team of researchers from the University of Birmingham have developed an electro optical infra-red shutter which is smaller, faster and quieter than current mechanical shutters. Their novel shutter allows control over available shutter speeds with the theoretical limit in the GHz frequencies regime, and is being tested in a laboratory setting to evaluate performance in the far IR range. The device is operable over selected, relatively narrow frequency bands, and allows stroboscopic and 3D measurements, while providing capability for high-frequency sampling rates needed to improve image quality and the signal-to-noise ratio. Additionally, it allows IR camera systems to operate without interference from laser-induced dazzle effects.

The inventors aim to extend capabilities of IR and thermal imaging into new markets and applications, such as gaming and position tracking. The technology will find lucrative markets in providing modifications to existing infrared camera and discriminative imaging systems, and to automotive 3D sensor systems. The researchers are seeking a commercial partner willing to either jointly develop this technology for a specific application under a licence agreement, or fund a spin out company to develop the technology.

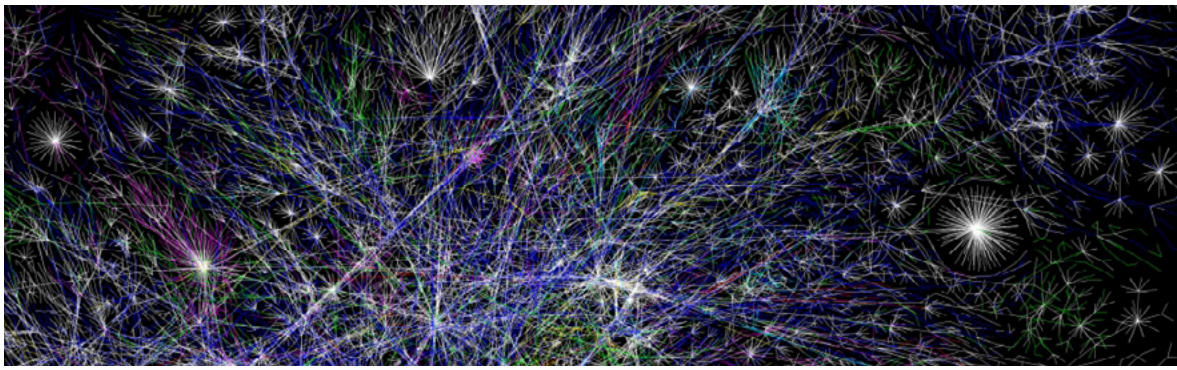
With so much visual data available due to the constant generation of video by mobile users, it has been realised that this huge quantity of data can be sourced, and channelled into practical use. PlaceMap: automatic indoor map construction using user movements is an indoor localisation system that utilises opportunistically-sensed data contributed by users. This system merges user-generated walking

BOX 3 : THE DIGITAL REVOLUTION

Starting in the 80's, this successor to the thrones of agriculture and industry has disrupted work, social lives and technology. Moore's law predicted the rise and shrink of transistors, which has allowed us to cram massive computing power into tiny devices. The same exponential improvements have affected software, meaning that the digital revolution marches inside our devices as much as it alters them physically. With ever more complex algorithms enabling deep learning and near-human AI, a new form of technological innovation is on the scene.

FISHEYE VIEW: The ESO's Very Large Telescope *(ESO/José Francisco Salgado)*

THE INTERNET:
A partial fingerprint of the web on the 15th January, 2005. *(Opte Project)*



segments with radio signal strength information to build a detailed map of walking paths.

One specific advantage of this novel system over existing technologies is the reduction of human effort. Unlike traditional survey methods for indoor localisation, users are free from labour-intensive site surveys and heavy system maintenance work. This invention uses a trajectory matching and floor plan construction algorithm to automatically cluster, filter and merge all user inputs to construct floor plans for different indoor areas. In addition, the system addresses the radio map building problem by creating a radio map simultaneously.

The technology, developed at the National University of Singapore, will naturally find a wide range of location-based applications, such as in the building of augmented reality apps that involve indoor environments, indoor navigation for shopping malls and other complex indoor areas, indoor localisation for 'Internet of Things' applications, ad-hoc floor plan mapping and a range of other applications for indoor localisation and floor plan construction. The team is currently at technology readiness level 5 and are excited to offer partnership for commercial development and opportunities for exclusive and non-exclusive licensing.

Advances in compact video recording technology have come with the development and implementation of more complex surveillance systems. With the increasing volume of videos being recorded, edited, stored and distributed globally - whether for purposes of social media or state-based security - the ability to tag video with a variety of metadata that can be used for storage and indexing will become increasingly useful.

A team of researchers at the National University of Singapore has developed 'GeoVid: capture and management of sensor-enhanced video'. The GeoVid system acquires and manages videos being tagged with sensor properties (metadata) of the camera during recording, such as geographic information. The collected and correlated metadata can then be used for storing, indexing and searching, large collections of videos in useful formats. With this system, videos of any kind can be better managed, searched and presented.

The GeoVid system consists of several acquisition applications for mobile devices and a sample video search portal. One of the novel GeoVid processing aspects is the use of an estimation model of a camera's viewable scene. For video acquisition, the system uses automated annotation software that captures videos, their respective field-of-views and other sensor information.

The applications for this system range from standard geo- and meta-tagging of video, to the incorporation of vital information and surveillance-related video data. The system, currently at TRL 6, is compatible with iOS and Android platforms. The designers are seeking industrial collaboration and investment to take this technology to market.

INNOVATION IN SOUND

The way technology can be utilised to enhance our perception and use of audio has applications in almost every aspect of our lives. Yet, the development of audio technologies may have lagged behind that of video and optoelectronics. There are, however, exciting developments being developed in universities, through which the digital manipulation and presentation of audio using novel technologies can be applied to enhance our day to day lives.

One such example is in mental health. Sensory problems are common in those affected by autism, with many suffers reported to have over- and under-sensitivity to a number of different sensory 'triggers' such as sight, sound and touch. Parents rate sensory problems as one of the top two areas of difficulty for family life. Increasingly, sound management technologies are emerging to help adults with a diagnosis of autism spectrum disorder and abnormal sound sensitivity.

Now, a team of researchers at Brunel University has developed a simple in-ear device that reduces uncomfortable external noise with minimal impact on normal conversation. This hybrid noise reduction device for cancelling high frequency sound dynamically intercepts and neutralises sounds in the higher frequency range that individuals with autism find specifically challenging.

The headphone device is

intended to allow patients to blank out extraneous noises, while still allowing wearers to hear and focus on conversations. Unlike crude sound blocking devices that block out speech and unwelcome sounds - and interfere with normal daily interactions - this technology has the potential to minimise the impact that unexpected and unmanaged sound sensitivity has on people with autism.

The researchers have worked with autism charities to develop this technology to a proof of concept level. They now seek partners to collaborate on its development, provide funding, and license this technology.

The distortion of many audio sources is a common problem, for example, indecipherable public address systems and hand-held recording devices will frequently deliver poor audio quality. Poor quality audio can have real consequences. User generated content is now used extensively in news broadcasting. But to successfully utilise this extensive resource of content, a rapid assessment method to determine if the audio quality is broadcast-worthy is required. Furthermore, if audio problems could be detected during recording, and feedback given to the operator of the device, this issue could be avoided altogether.

To this end, researchers at the University of Salford has developed an audio quality control software for distorted sound that detects and quantifies the degree of distortion a listener would perceive in an audio file. This enables metadata associated with the quality of the audio file to be generated and acted upon. The software tool uses a 'single ended', 'blind' assessment so no prior knowledge about the source or reproduction chain is required. Its applications, including media asset management systems, will enable editors and broadcasters to select media assets with appropriate audio quality for broadcast. Integration into recording devices will allow real-time user assessment of recording quality.

The software is currently protected by copyright with the key algorithms confidential. The researchers are investigating patent protection as part of their commercialization strategy, for which they seek partners interested in collaboration and licensing.

MICHAEL MONGIN

FIGURE 5. ***AN INVISIBLE METRONOME:*** 'Acoustically Transparent Headphones' developed at the University of South Wales offer musicians the ability to clearly and simultaneously hear themselves, band-mates and a backing track.

Sound quality is also of vital importance to musicians. Professional recording artists spend many years learning to play their instrument, and throughout that time the single most important thing they pursue is a personal sound: a tone of the highest quality. But a problem occurs in the recording studio when a partly recorded track or a "click track" is played back through headphones and the musician is asked to play along.

Up until now the solution is to 'fold back' the musicians' sound into a headphone mix. But that sound is from the microphone - usually placed in front of the instrument - and is very different in quality from the sound at the musicians' ears; so much so that most musicians will wear headphones on one ear only or perhaps even use single sided headphones made especially for this purpose.

Now, experts in music technology in the Faculty of Creative Industries at the University of South Wales have developed acoustically transparent headphones to improve musical performance *(Figure 5)*. This novel device enables musicians to hear the environment around them – as if not wearing headphones at all - whilst benefiting from natural binaural fold back, making it significantly easier to play in tune with a good tone. Musicians in a group can identify their own sound as well as the sounds of the other performers, all while helping to avoid hearing damage.

The technology can be employed as headphones or as an in-ear device, and is applicable to live stage performance as well as studio recording. The researchers are actively seeking companies interested in licensing and collaborative partnerships to further develop the technology.

When we watch a person speak, our ears and eyes receive signals at different times. Research shows that audio-visual integration is naturally suboptimal in the majority of individuals. Despite this asynchrony, speech comprehension still benefits from integrating lip movements. Research suggests that such speech reading can benefit even more from artificially correcting the asynchrony. This is particularly important for people with hearing aids or people with speech/hearing impediments.

A unique solution has been

GEORGE GROUTAS

FIGURE 6. *OBJECT-BASED AUDIO:* A system developed by researchers at the University of Salford allows sound to be spatially located, recorded, mixed and edited together for immersive broadcasting.

developed by researchers at City University London that allows an individual to calibrate their asynchronies in order to identify personally-optimised audio-visual synchronies to enhance hearing, perception and performance response. Optimising audio-visual integration is of particular benefit in cases of mild to moderate hearing impairment.

By taking vision into account, this technology will be very important to the design of the next generation of hearing devices. In addition, there is scope for implementation in the fields of speech therapy and language training, highly lucrative entertainment, such as gaming and virtual reality, and sporting equipment. The benefits of this technology will be reaped by any application that delivers audio-visual sensory stimulation by optimizing the ability to hear and perceive simultaneously. The creators seek parties interested in licensing.

With the advent of mainstream 3D cinema and emerging technologies, such as the Oculus Rift, which aim to provide a fully immersive experience, the development of audio technology has failed to match the rate of visual technology change.

However, a team from the University of Salford has developed object-based audio software that can change the way audio feeds are recorded, edited and broadcast. This software enables key sounds within a feed, for e.g. live sports' broadcasts, to be identified, extracted and spatially located. This could be the kicking of a football on a pitch, or the blowing of a whistle from the sidelines *(Figure 6)*.

Combined with automated sound mixing, this technology could - in the future - enable individuals to self-edit the audio feed of a broadcast for an immersive experience. This technology benefits from automatic storage of individual "audio objects". These objects can be recombined for a specific listener experience, and individual sounds can be amplified for dramatic effect by automatic live mixing, which conventionally required an experienced sound engineer.

The equipment operates with a <1 second delay, and locates the physical origin of sounds within 30 cm. Currently, the team have a prototype system which has been demonstrated with a Premier League broadcast feed. They are seeking commercial partnerships for further development and trials with the option of exclusive rights to license the technology.

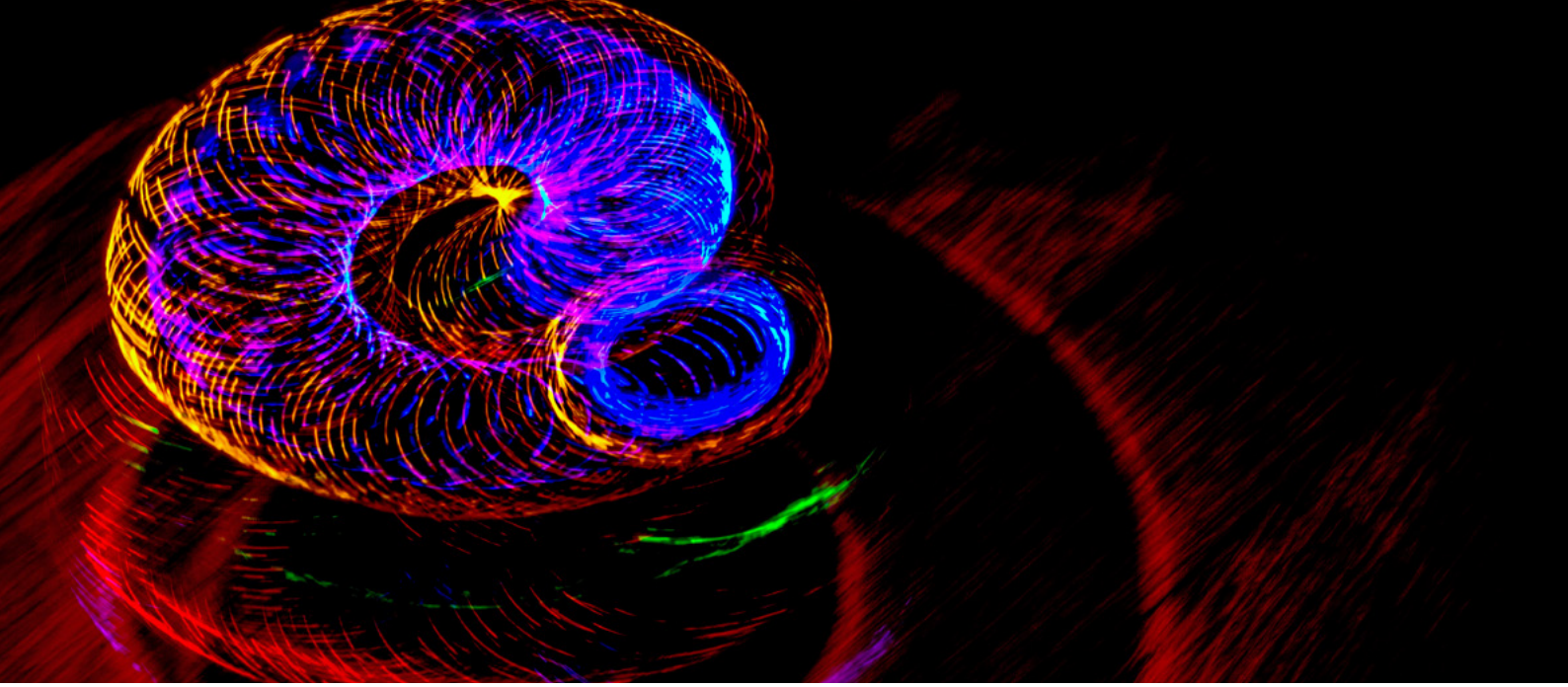
Audio mining is a common technique for searching audio databases or archives for specific content, such as spoken words or phrases. With media archives continually growing in size, there is an ever-increasing demand for automated metadata generation, indexing, and search functionality.

One challenge to current methods of audio mining is classifying recordings containing overlapping audio sources of speech, music, event noises, and ambient sounds. Machine audition and music information retrieval tools have been developed for specific sound retrieval, but combined use of these systems is poorly developed. Therefore, sources of diverse audio overlap can compromise the classification of different sounds, resulting in poor recognition and/or missing content, and ultimately reduce the usability of audio archives.

This has led researchers at the University of Salford to develop an audio classification tool for efficient archiving and search. This innovative tool implements a non-exclusive classification system to identify overlapping sounds from different sources and provide a time stamp for individual elements of audio content.

By employing iterative signal clearing techniques, this tool is capable of classifying arbitrary audio signals into music, speech, ambient sounds and silence, whilst simultaneously providing useful time-stamp information for each source. This technique eliminates information losses embedded in a soundtrack during machine audition and audio retrieval processes, significantly improving usability and reliability.

The immediate applications for this system will be focused on integration into existing audio archive search software to vastly improve usability, efficiency and accuracy of the audio mining process. Subsequently, it will allow significant improvements to speech recognition software, and enable translation of speech into text regardless of the background sound. The developers seek collaboration and licensing of this proprietary, copyright-protected software.



Future Information & Communications Technology

How we think about information is constantly changing; the way we communicate and use information in the future will be vastly different from today. Quantum theory, holography, neural networks and robotics will spur changes which are difficult to foresee. In this final chapter we take a look into the Brave New World of tomorrow, and explore the novel ways we can start to think about, produce and communicate information.

THE INTERNET OF THINGS

The Internet of Things (IoT) is all around us. But, unlike the data and electromagnetic streams that convey and constitute the internet itself, the IoT is the physical network of objects that enables these streams: the phone in your pocket; your broadband router; the telephone pole outside. Vehicles, buildings and other items embedded with electronics, software, sensors, and network connectivity all comprise the IoT. As the network becomes increasingly complex, more and more devices will become part of it.

A significant challenge to be overcome is how to provide the electrical power required by the hardware that makes up the IoT. One solution is to harness the energy that surrounds us in the form of heat, movement and light, and convert it into electrical energy – a process termed energy harvesting.

Identical in principle to renewable power generation, powering the internet of things is a novel technological roadmap for generating such electrical energy on a much smaller scale, typically ranging from micro- to milliwatts of power. Such independent power sources offer the potential to locally power each 'thing' indefinitely and without intervention.

The University of Southampton has been leading the field of energy harvesting for over 15 years and has demonstrated a range of harvesters and energy harvesting powered systems that work from vibrations, human motion, temperature gradients and airflow. This could become an essential enabling technology for the IoT. The inventors have to-date harvested energy using a wide range of technologies such as the conversion of vibrations into electrical energy using active materials and electromagnetics.

In 2007, they demonstrated the smallest electromagnetic energy harvesting powered system, which was able to harvest energy from vibrations almost undetectable by touch.

ROBERT COUSE-BAKER / FLICKR

The spin-off company Perpetuum was created to commercialize this technology.

The researchers at the University of Southampton now seek to exploit recent developments in materials and devices in collaboration with partners interested in the IoT and any other applications where an independent, maintenance-free power supply is required.

Another arena in which novel sources of power generation is a hot topic is the ever-growing market for wearable technology. These devices have the potential to transform how people experience the world, with practical functions or aesthetic features introduced into clothing and accessories of daily life. Wearable technologies currently rely on batteries that require periodic replacement or frequent recharging via separate docking stations or cables. This limitation could be eliminated by wireless power transfer, in which coupled electromagnetic waves transfer energy between a pair of coils. This type of technology already recharges mobile phones. Now, researchers at the University of Southampton have developed a way for flexible coils to be inserted in textiles, enabling power transfer between upholstered furniture and clothing. This technology allows wireless power transfer for wearable technologies: the potential to recharge wearable technology and portable devices whilst sitting in your favourite seat without actively doing anything at all.

To date, the designers have assembled a demonstrator comprising of a chair and jacket that together are able to recharge a standard mobile phone. The associated electronics have been optimised to maximise the range and coverage of the wireless power transfer, and the system operates at perfectly safe power levels - well within maximum limits for human exposure.

Further work will be required to build a practical system and improve the range and levels of power transfer. Collaboration with designers and potential users of the technology is sought to develop the system further and optimise it for use in specific applications.

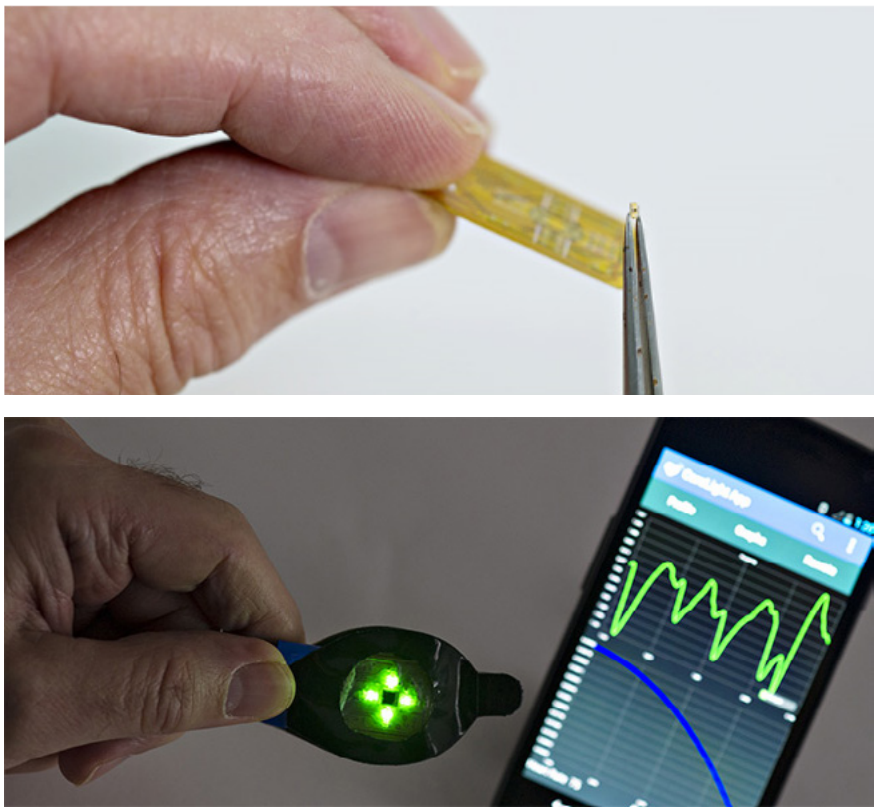


FIGURE 7. *WEARABLE HEALTH MONITORING:* 'Carelight' from Loughborough University: *(top)* a miniaturised optical patch sensor which delivers strong and constant signals unaffected by motion, sweat, skin composition or pigmentation; (bottom) the packaged product which has multi-sector potential in healthcare, military, sport and fitness, and hazardous environments.

One of the most lucrative areas of application for wearable tech is in healthcare and wellbeing. The ability to cheaply and effectively measure specific physiological parameters is especially important to those who require round-the-clock observation or treatment.

However, the more people move, the more difficult it is to accurately monitor physiological parameters such as heart rate, oxygen levels, respiration and blood pressure. Many will be familiar with portable heart rate monitors which can be uncomfortable and impractical to use routinely. More user-friendly approaches have emerged based on the use of photoplethysmography (PPG), an optical approach that can measure multiple and critical parameters in addition to heart rate.

A team of researchers at Loughborough University has developed Carelight: a wearable sensor for real-time, continuous monitoring of vital signs *(Figure 7)*. This ultra-lightweight wearable PPG sensor can be placed on various parts of the body to provide reliable, continuous monitoring of a range of vital signs including heart rate, respiration rate, heart rate variability, blood pressure, temperature and oxygenation levels.

Carelight is aimed at the emerging market of wearable technology, and does not require extensive technical equipment. A patent application has been filed to protect the technology and the inventors are now looking for commercial partners to take the technology into regulated healthcare markets.

ROBOTICS & NEURAL NETWORKS

Robots are now a mainstay of the manufacturing environment, performing highly complex tasks more rapidly and with greater consistency than humans are capable of. However, many robotic devices suffer from a limited repertoire of tasks they can perform.

Specifically, robotic hands are typically designed to perform a limited number of actions for which the hand has been specifically designed. Current robotic hands also have a very limited ability to learn a grasp for a novel object. The ability for a robotic hand to determine the optimal spatial relationship between each part of itself and the surface contours of an object would maximize the likelihood of a grasp being effective.

Researchers at the University of Birmingham have developed an algorithm which allows robotic devices to do just this. The algorithm generates many possible robotic grasps, and then selects the optimal one. This allows the robot to pick up varied objects, including fragile and novel items, with one hand *(Figure 8)*.

The team has also developed a novel configuration model that captures a set of hand shapes which comply with the demonstrated grasp learned through initial contact. This allows a set of corresponding poses to be simultaneously realised without diverging from the demonstration grasp.

The potential applications and markets for these innovations are vast, encompassing diverse global manufacturing environments where products and components frequently vary in size shape and form. It could also be tailored for highly specific applications where safety is a concern, such as bomb disposal or the handling of nuclear materials. Patent applications have been filed in Europe and US, and the researchers are seeking collaboration and partnership with industry to develop this into commercial technologies.

BOX 4 : ARTIFICIAL NEURAL NETWORKS

Artificial neural networks are a family of models inspired by biological neural networks, such as the mammalian brain, and are used to estimate functions that depend on a large number of unknown inputs *(See IBM's Feature Editorial, p. 31)*. These networks are generally presented as systems of interconnected "neurons" which exchange messages between each other and are capable of learning.

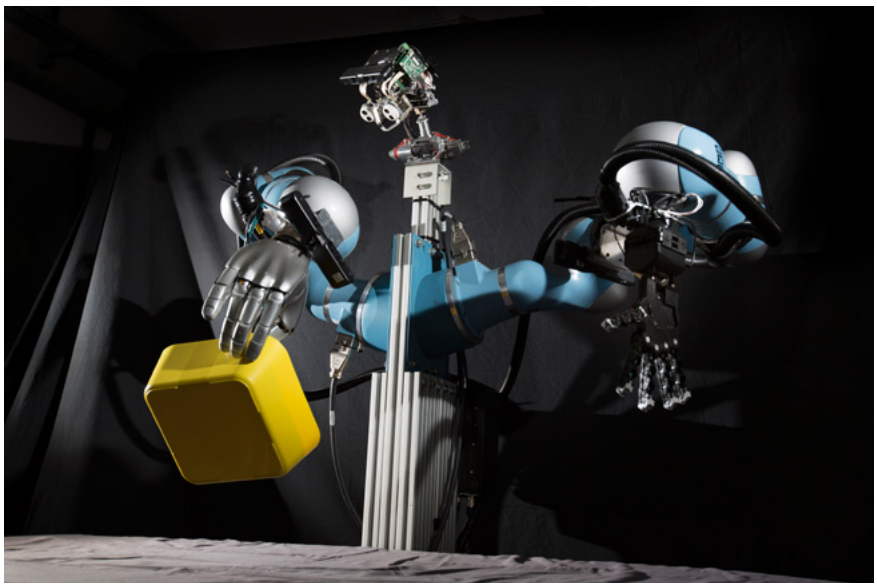


FIGURE 8. ***SPATIALLY-AWARE ROBOTICS:*** Algorithms developed at the University of Birmingham empower robots with the ability to learn how to optimally grip objects of varying size, texture. shape and form.

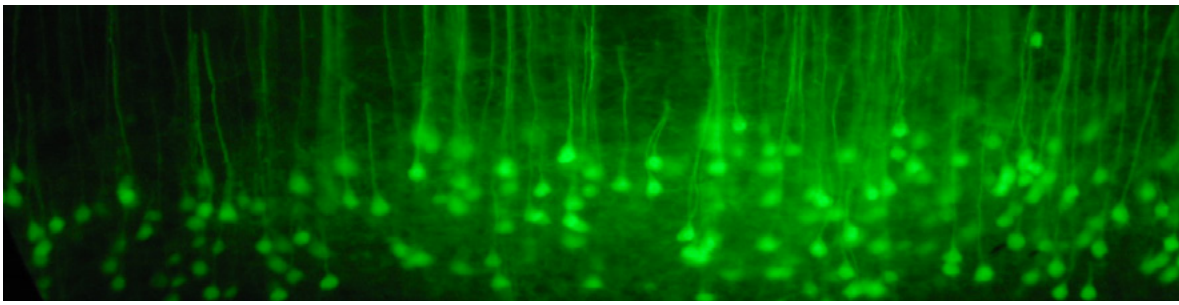
Another arena in which robotics has enabled significant progress is in prosthetics. While the design of technologically-complex prosthetic limbs has improved enormously, these devices still offer a limited range of movement and functionality. In large part this is due to the difficulty of channelling the signals intercepted from the nervous system intended to control the limb.

Increasingly, researchers are attempting to artificially simulate the neurological behaviour of the human body in order to guide prosthetic limbs with the patient's own neurological systems. Therefore, the behaviour of the chosen communication channel in such simulated systems is of utmost importance.

As in most communication channels, those within the body - for example sending instructions from the brain to arm muscles - introduce a certain amount of noise to the transmitted signal. Characterisation of the noise generated is critical for the development and optimization of robotic and prosthetic technologies.

Researchers at Plymouth University have discovered that the noise characteristics of the neurological channels within the human body result in the introduction of "proportional noise". This means that the standard deviation of the noise is proportional to the signal strength, and is markedly different to conventional engineered communications systems.

The identification that the current communication channels within the human body follow a proportional noise model compared with a Poisson noise model - which has previously been assumed in artificial systems - offers new opportunities for controlling



NEURONS: New information networks take inspiration from nature *(Robert Cudmore)*

signal noise and erratic movements in prosthetic limbs and robotic arms. The team is now seeking investment and collaboration to commercialize this technology.

Neurological and neuropsychiatric disorders severely reduce the quality of life for those affected, and carry significant societal and economic costs. The Centre for Disease Control and Prevention estimates that over 600,000 individuals in the US experience a stroke each year, and over 275,000 individuals suffer traumatic head injuries requiring hospitalization. Many individuals never fully recover from these injuries due to one or more cognitive disabilities. Currently, there is no effective treatment for these neural disorders.

To address this issue, researchers at Princeton University are developing adaptive cognitive prosthetics to treat neurological and neuropsychiatric disorders and traumatic brain injuries. This device, supported by a novel hierarchical learning algorithm, can learn to replace the neural function lost to a brain injury or neural disorder.

It bypasses damaged regions of the brain and mimics lost functionality by recording the neural activity from other brain regions. Crucially, this mapping from inputs to outputs must be learned for each individual and for each lost cognitive function. This allows the prosthetic to produce the neural stimulation patterns needed to facilitate exactly those behaviours that are disrupted.

Ultimately, the team at Princeton hopes to be able to recover the function of brain regions damaged either through traumatic brain injury, stroke, and even to treat neurological and neurodegenerative disorders such as Parkinson's and Alzheimer's. The researchers are seeking collaborators who can help bring this incredibly exciting technology to the market.

With renewable energy becoming increasingly prevalent, there are more microgenerators being connected to the grid. This influences grid power quality and results in higher costs for grid operators. The grid is considered as a complex network which needs to constantly adapt to new nodes, that both use and produce energy, therefore the grid should be treated as a neural network *(Box 4)*.

Using this principle, a team of researchers from City University London have developed technology that offers neural net grid control (NNGC). Their technology is based on controlling a single recurrent neural network which allows the grid's neural network to adapt in real time without the need for continual neural network retraining. This means faster stabilisation of grid power quality than existing systems as there is no retraining of the neural network needed at run time as the neural connections are fixed. This makes the neural network controller extremely computationally efficient at run time.

NNGC reacts more intelligently and optimally than a proportional-integral-derivative controller, which enables it to reduce overshoot and settling time, while maintaining excellent overall performance. This technology is a cost effective solution for electric utility companies and customers. The software that has been developed is highly scalable, totally secure and completely maintainable, and has passed the proof of concept stage. The developers now seek industrial collaboration to co-develop this project, including further testing and the construction of hardware.

WIRELESS SENSING & MONITORING

The ability to monitor and store data from systems in real time, as well as recall and analyse that data, is vital to modern industries and infrastructure. As machines and networks become more complex and integrated, so too must our capacity to monitor them.

Health and usage monitoring systems (HUMS) are used in aircraft to monitor various systems, such as engine and gearbox performance, by collecting and analysing data from a range of sensors. At the moment, wired sensors are widely used but their installation and maintenance costs are extremely high. Batteries, as the primary power supply for wireless sensors, have a limited lifetime and frequently require maintenance.

However, by harvesting power from the environment, this issue is removed, and wireless sensors can be deployed simply and effectively throughout an aircraft, or other environment requiring monitoring. Recent work at the University of Southampton's Zepler Institute has demonstrated the viability of powering such sensors from ambient vibration. This research has resulted in two self-powered wireless sensors for distributed health and usage monitoring.

The first is a credit card-sized, self-powered sensor demonstrator which used a helicopter's vibrations to generate 240 μW in current. This

FIGURE 9. *NON-DESTRUCTIVE TESTING:* 'Inductosense', developed by researchers at the University of Bristol, incorporates inductively-powered, embedded sensors to offer sophisticated sensing for myriad applications.

demonstrator allowed the sensory node to transmit information every ten minutes.

The second, a low-profile electromagnetic energy harvester has also been developed. It has the smallest thickness among all reported non-microelectromechanical electromagnetic energy harvesters, generating 450 μW of power when excited under the same conditions.

These 'fit and forget' technologies promise easy deployment, and would be ideally suitable for retrofitting on existing aircrafts, offering a long-term power solution, with low maintenance costs. The developers are interested in collaborating with industrial partners to take these devices to market.

Sensors that do not require an external source of power have also been developed by researchers from the University of Bristol. 'Inductosense', wireless embedded sensing, is a system of permanent, wireless passive sensors attached to, or embedded into, a structure *(Figure 9)*.

The power and signal are provided by non-contact inductive coupling from a measurement probe. These light and thin sensors are fixed in place, alleviating the possibility of human error, especially for repeated measurements over a protracted period. This means unskilled operators can undertake sophisticated and auditable non-destructive testing and measurements can be made robotically. Sensors can be placed in areas that are usually inaccessible, or even embedded into a structure such as a composite aircraft wing. Furthermore, the inductive coupling system can also be designed with other types of sensor.

These sensors would be ideal for applications associated with oil and gas pipelines and vessels, aerospace, and power generation systems. The researchers are currently evaluating the potential for a spinoff company based on this technology, and they are interested in talking to potential industry users about their needs and applications.

Another area in which sensors and monitoring technology are of vital importance to productivity and profitability is manufacturing. Inspecting the structural integrity of manufactured parts with high accuracy is a challenging, expensive, and time-consuming process. Traditional quality and conformance checks during the making or inspecting of high value parts, such as containers used in the nuclear industry, can delay and lengthen the production cycle.

A team from the University of Strathclyde has developed a suite of automated inspection techniques for the automated non-destructive evaluation of components, combining unique elements of sensors, robotics and advanced signal processing. By automating the inspection and evaluation process with industrial robots, significant reductions in production time with concurrent improvements in accuracy and reliability can be achieved. This enables inspection staff to process and monitor the much larger volume of measurement data.

This fully automated technology can be made to incorporate multiple non-destructive inspection techniques. It is fully scalable and flexible for any component size, and so will benefit many markets and applications, such as nuclear, health, oil & gas, automotive and aerospace. The university is currently gathering industry feedback to evaluate the world-wide market for this non-destructive quality control technology with the aim of commercialisation.

QUANTUM COMMUNICATION

Quantum theory is as exciting as it is disturbing . Its mathematics produces a mess of logical contradictions, yet likely holds the key to the future of computing. The application of quantum theory to the design of technology opens up a vast range of exciting avenues that are only beginning to be explored. One such example is in the use of the quantum properties of light in communications.

One of the key properties of light is its orbital angular momentum (OAM). Research into OAM has suggested that light waves could carry unprecedented quantities of data through optical fibres and represent a new optical degree of freedom yet to be utilised by industry.

The simplest form of OAM is an optical vortex, which is a beam of light

whose phase varies in a corkscrew-like manner along the beam's direction of propagation. The OAM carried in such a field enables it to trap and rotate colloid particles and living cells as a so-called "optical spanner" for use in biophysics, micromechanics or microfluidics. OAM also has the potential to be used in super-high optical data storage, enhanced data transmission, imaging, metrology, and communications.

Building on current technology, the University of Bristol has developed a compact source of laser light with a specific orbital angular momentum state. This represents a novel way of generating light with OAM in an extremely low-cost and compact form that can be simply integration on a chip.

Large arrays of over 1000 emitters with different OAM states can be, for the first time, fabricated with vast potential applications in chip-to-chip interconnect technology. This will also facilitate more complex optical manipulation schemes in biophysics.

The emitter can be tuned on the chip to emit specific OAM states, and also has the potential to work in reverse to detect specific OAM states. Currently, the patent for this technology is pending, and the inventors are offering opportunities to collaborate in the further development of this technology in order to take this to market.

Nanoparticles are an exciting area of research due to their utility in packaging and delivering other molecules in a targeted fashion within biological systems, for example the delivery of therapeutic drugs to cells within the body. However, the manufacture of nanoparticles is complex, and the properties of different types of particle have to be tailored to each specific purpose.

Crystallinity has a profound effect on the physical properties of a nanoparticle. The development of effective and useful nanoparticles is dependent on the ability to control the level of crystallinity, and the limitations in doing this effectively are holding back the use of nanoparticles in advanced applications.

To tackle this limitation, researchers from the Okinawa Institute of Science and Technology have developed a process for the metal-induced crystallization of amorphous silicon quantum dots. This technology uses metal-induced crystallization to elegantly control the final crystallinity of the nanoparticles, creating nanoparticles that are amorphous, monocrystalline or polycrystalline. Essentially, the desired physical properties for any specific application can be obtained.

The applications for this technology include hydrogen storage, multimodal bio-imaging, biosensors, solar cells and other optoelectronic devices. The technology can be applied to a range of metals including aluminium, gold, nickel, palladium and copper and is applicable to silicon, germanium, and silicon/germanium quantum dots. This technology promises to revolutionise the use of nanoparticles and OIST is offering opportunities to license or collaborate on the development of this technology.

HOLOGRAPHY

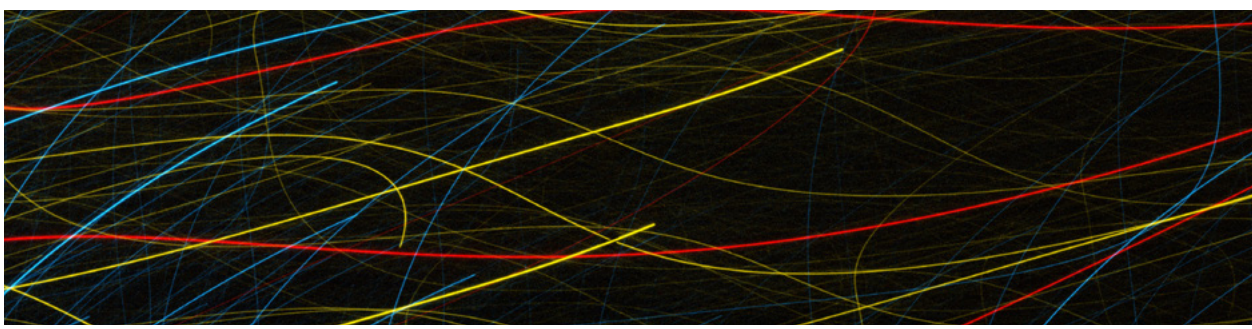
The word hologram refers either to a physical structure that diffracts light into an image, or the image generated by this process. We are all familiar with the ghostly holograms of science fiction, but the technological developments taking place in the real world are now producing holographic technologies that are equally exciting and visually stunning.

To successfully produce brighter holographic images, the ratio of light intensity forming the image to that of the incident light has to be improved. However, increasing this 'holographic efficiency' is hard to achieve in computer generated holograms (CGHs).

Numerous factors, including low diffraction efficiency, twin images, expensive and error prone fabrication techniques, result in poor signal-to-noise ratio and poor uniformity, and are all unresolved problems. Using conventionally available methods, hologram efficiency remains too low at visible wavelengths for practical purposes.

Highly efficient metasurface holograms are the answer to this limitation. This technology, which utilizes geometric metasurfaces to give superior phase control of incident light and achieve high holographic efficiency, has been developed by researchers based at the University of Birmingham. It results in overall holographic efficiency with significantly brighter holographic images.

These metasurfaces are relatively



QUANTA: Packets of light *(Hubble ESA)*

simple to manufacture and avoid the need for complex three dimensional structures, and are therefore less expensive than traditional multiple-level phase control devices. Using nano-imprinting, large-scale manufacturing at a low cost is feasible.

Computer-generated graphics are the future of computer-aided design, gaming, and many other forms of entertainment. The technology can also be utilised for security (for example, optical anti-counterfeiting), head-mounted displays or in defence applications (such as missile guidance system). The researchers are seeking commercial partners interested in either developing this highly lucrative technology under a licence agreement, or funding a spinoff company to develop the technology as a platform for a variety of markets.

Scientists in various fields use digital holographic microscopy for the collection of three-dimensional information about a sample or object of interest. However, the use of such devices in research is often limited by the expense, as the microscopes are extremely complex and require specialized objective lenses.

Now, researchers at Rockefeller University have developed an inexpensive and portable holography device that can convert a digital camera into a holographic microscope. This attachment is extremely versatile and inexpensive, and is compatible with any digital camera, including those that are part of a cellular phone. The device can perform holographic imaging effectively with extremely high lateral resolution, and is battery-operated and portable, making it suitable for use in the field.

The inventors are confident that this technology will play an important role in biological microscopy and in the fields of fluid dynamics, particle tracking and as an environmental screening device. Currently the team have built a functional prototype, and with patent pending they seek partners for development, investment and collaboration.

BIOPHOTONICS & ICT IN HEALTHCARE

The treatment of all human diseases relies on an accurate diagnosis. The personalised medicines of tomorrow will only be possible if we can rapidly and effectively obtain the individual biological characteristics of the patient at the cellular and molecular level. This necessitates the accurate detection of specific biomolecules present in the body or specific cells and tissues, which indicate the presence of an infection or disease of some kind.

Technological advancements in sensors that can detect clinically relevant concentrations of these 'biomarkers' at a high speed will be essential for the future success of recent developments in personalised medicine and healthcare. In addition, costs will have to be low if developments are to benefit a large number of patients.

Photonic biosensors represent one of the most sensitive disease biomarker detection technologies available, which is exemplified by the high performance instruments offered by, for example, Biacore and Genalyte. However, one key issue is that these are extremely expensive; this has been a major hurdle in the proliferation of the technology into the clinic.

Now, researchers at the University of York have developed a high sensitivity, photonic silicon biosensor with simple camera readout *(Figure 10)*. The sensor consists of a resonant grating which is illuminated by a semiconductor laser of fixed wavelength. The grating resonance shifts when the target biomarker binds to a specific biological molecule, for example DNA or an antibody, which ensures the specificity of the sensor. The sensor's sensitivity is on the nanomolar level, possibly lower.

A key benefit of this technology is that the resulting shift can be detected directly by a generic imaging sensor, such as a smartphone or complementary metal-oxide-semiconductor camera, without additional instrumentation required. The technology is intrinsically simple and robust, and does not compromise performance.

Together with appropriate biochemical functionalisation, the sensor can be sensitised for any disease for which antibodies are available and so will find a wide range of applications within commercial and public healthcare provision, and specific medical research applications. Presently, a number of generic patents that cover the invention are about to expire, and the inventors would like to develop new, patentable IP together with a commercial partner.

The majority of current diagnostic methods for chronic diseases such as cancer, rely upon time-consuming tests requiring skilled scientists or clinicians. Specific biochemicals or tissue architecture must be assessed which can be subject to observer variation resulting in the need for repeat testing, delays and incorrect diagnoses, all of which impact upon patient management.

Researchers at the University of Strathclyde have used two example disease states - brain cancer and sepsis - to establish a rapid technique for the quantitative analysis of protein structure, and a method of quantum cascade laser spectroscopy for use as a clinical tool. 'CLINSPEC: developing objective clinical spectral diagnostics', is a rapid, efficient and easy-to-use tool for the accurate identification of structure and composition from complex mixtures. It also simultaneously probes the biomolecular content of tissues, promising to revolutionise clinical diagnosis. Its reliance on infrared spectroscopy is ideal for clinical implementation due to its rapidity, ease of use and ability to provide objective characterisation of biofluids and tissues, thus enabling quantitative profiling of protein composition.

Though initially limited to two specific disease states, the applications of the finished technology will be broad, and will encompass most

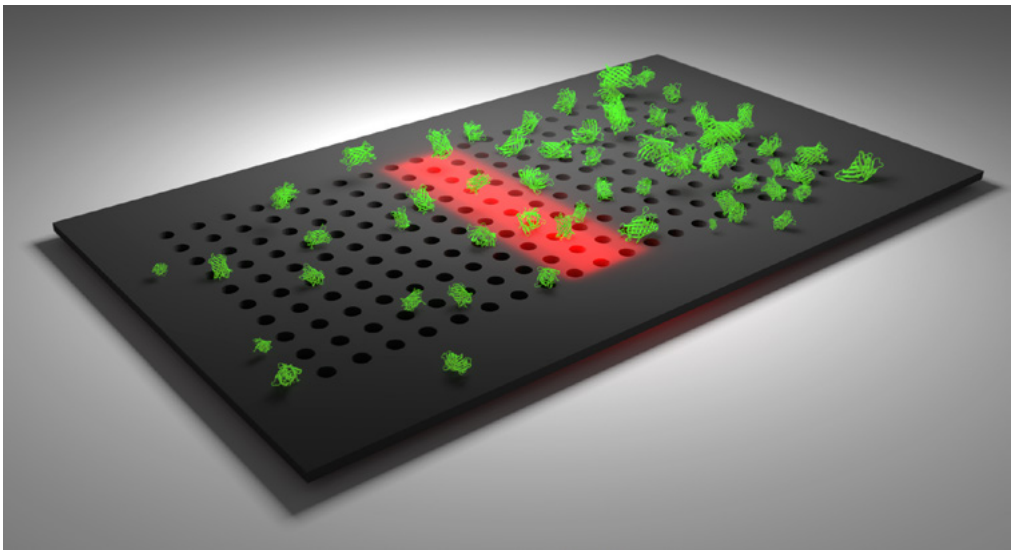


FIGURE 10.
***UNIVERSAL SENSING*:**
Developed at the University of York, this versatile, low-cost biosensor can be sensitised to detect any known antibody

imaginable forms of neoplastic and infectious disease. To reach this end goal, the researchers are seeking partners for further development and collaboration.

Small biosensors have myriad applications within biological detection and diagnostics, but also in other fields where minute detection levels are required. Indeed, compact, mass-produced biosensors and analytical microsystems are required for biochemical monitoring of water quality as well as in personal and preventative medicine.

To date, producing such small biosensors required the same microfabrication approaches that have broadly advanced consumer electronics over recent years. However, the degree of optical functionality integrated within these systems remains extremely limited. The mid-infrared spectral region covering wavelengths between 2μm and 20μm can provide far more information on biochemical species through direct absorption, i.e. 'fingerprinting'.

Microdevices operating in this spectral regime remain in their infancy, but researchers at the University of Southampton are aiming to generate standardised, highly sensitive, mass-producible, mid-IR waveguide devices for biomonitoring and sensing mass. These devices will be used in applications such as immunosensing for water pollution, refractometric waveguide immunosensors, and specific and highly-sensitive, fluorescence-based multiple immunosensor chips for simultaneous detection of up to 32 analytes.

The developers have worked collaboratively to realise and validate numerous complete systems, and have established materials and waveguides for mid-IR operation and an advanced mid-IR characterisation suite. They now seek collaboration partners in both basic science and specific design-led applications to harness the massive growth in photonics telecommunications technologies, and develop the next generation of bioanalytical devices.

The ability to harvest the extremities of the electromagnetic spectrum, such as T-rays, T-waves, and T-light in the THz frequencies, offers enormous potential for chemical and biochemical analysis, but remains prohibitively expensive. In developing technologies that exploit these sub-millimetre waves, much of this cost lies in the pump laser, often a Ti-sapphire laser or fibre laser. In addition, selection is severely restricted by the lack of photoconductive detectors and emitters tuned to wavelengths other than 800nm, and 1.06 or 1.55 μm.

Graphene has well understood optoelectronic properties within the electromagnetic spectrum, including unique characteristics in the terahertz band, and now, scientists at the University of Leeds have developed a methodology for manipulating this famously tricky material to utilise these characteristics in applications.

Graphene has been employed on an on-chip THz frequency detector and emitter which equals the performance of the incumbent technology 'low temperature GaAs' (at 800nm). The graphene THz detector for time domain spectroscopy is currently being developed for free space use, and for use at alternative pump wavelengths. It is expected that these detectors and emitters will be the enabling technology for system designers to create cheaper and higher specification TDS systems.

The team at the University of Leeds are currently undertaking research on the free space properties of graphene detectors at a variety of key, near-IR wavelengths, for example 1.5 μm. These results, which will also include characterisation of graphene as an emitter as well as detector, will be available soon. The developers are looking to engage with external organisations, with a view to further development and licensing for specific applications.

UNIVERSITY HIGHLIGHT:

Securing the Global Information Network

Fighting cybercrime with state-of-the-art security systems and digital forensics

University of South Wales
Prifysgol De Cymru

Researchers at the University of South Wales (USW) are developing research programmes that focus on cybercrime challenges. Working with industry, government, and other educational institutions, USW aims to address a worldwide lack of cyber security experts, while providing expertise to the security industry.

The Information Security Research Group (IRSG) at USW has an international reputation in network security, computer forensics and threat analysis. It maintains two specialized research labs – the Network Security Research Laboratory (NSRL) and the Computer Forensics Research Laboratory (CFRL).

Driven by the needs of law enforcement departments across the UK, researchers at the CFRL focus on computer forensics and data recovery. Key to this research is developing novel solutions to various forensic/data-recovery problems, as well as the exploitation and technology transfer of results back into UK law enforcement systems. Most recently, the CFRL has been at the forefront of developing a unique automobile forensic data recovery capability, headed up by computer forensics expert Gareth Davies.

> “Cyber crime is seen by the UK Government as one of the four major national security threats facing the country.”
>
> - Eric Llewellyn,
> *Associate Head of Computing and Mathematics:*
> **University of South Wales**

Amongst other secured infrastructure, the Network Security Research Laboratory contains an isolated network that simulates the internet and various wireless networks. It is here where experiments concerning new threats are conducted. A state-of-the-art intrusion detection system is used, along with a local cloud, to analyse passwords and encrypted files. The cloud is also used for the development of a new generation of intrusion detection system.

In addition to leading this research, the Information Security Research Group (IRSG) at USW undertakes consultancy for a wide range of organisations. It is responsible for investigating and analysing a large number of both civil and criminal cases each year - using computer forensic investigations, and involving everything from GPS and mobile phones, to laptops and automobile systems.

USW is a pioneer in the complex physical repair of electromagnetic hard disk components, and NAND Flash memory devices, enabling a multitude of evidence to be recovered. To ensure that this expertise is shared, USW has recently launched a number of new initiatives. The National Cyber Security Academy and the European-wide ICT security partnership DECAMP, of which USW is a partner, aim to develop students' cyber security skills.

USW / THINKSTOCK

A CLOSER LOOK:

THE NATIONAL CYBER SECURITY ACADEMY

USW and the Welsh Government have joined forces on a £500,000 project to address the worldwide lack of cyber security experts. The pilot NCSA is being set up at USW's Newport City Campus, and will take its first students in October.

Also involving Welsh digital innovation company Innovation Point, and major industry players – including Airbus, General Dynamics, Alert Logic, Information Assurance, QinetiQ, Silcox Information Security, Westgate Cyber, and Wolfberry – the NCSA will work to close an expected skills gap in the cyber security sector. By 2019, it is forecast that an additional 4.5m personnel will be needed worldwide.

With support from the Welsh Government, the NCSA pilot involves 11 current USW Computer Forensics and Computer Security undergraduates. They will work on real-world projects set by NCSA partners, while also 'flight testing' the course to ensure it meets the latest cyber security challenges. It will develop as industry partners identify new cyber security challenges.

"Cyber crime is seen by the UK Government as one of the four major national security threats facing the country," said Eric Llewellyn, Associate Head of Computing and Mathematics in USW's Faculty of Computing, Engineering and Science.

"Meanwhile - according to research by the Ponemon Institute - 39 major companies in the UK faced costs of between £630,000 and £16m in fighting cybercrime last year.

"Both government and business understand there is a growing need for graduates with hands-on skills that can fight cyber threats. That's the demand that the NCSA will address. Putting students and industry together to come up with solutions to online problems.

"For industry, it offers direct access to a pool of graduates who have been trained to the highest standards and who have a clear understanding of cyber threats, while, for the students, it will maximise the opportunities for them to get a job when they leave."

COLLABORATION INSIGHT:

OPEN DISTRIBUTED EUROPEAN VIRTUAL CAMPUS ON ICT SECURITY

The University of South Wales is also working with European partners to train the next generation of computer security experts. USW has become part of the ICT security partnership DECAMP (Open Distributed European Virtual Campus on ICT Security), which was developed in 2014 to deal with a lack of ICT security experts in Europe.

Different aspects of the sector are being addressed at six universities across the continent - USW will focus on applied forensics, Munich University of Applied Sciences (MUAS) will work on network management and computer networks, Padua University in Italy will focus on wireless networking, eHealth systems will be the specialty of Bucharest University, web applications will be taught by Helsinki University, and Cantabria, Spain, will focus on cloud networking.

Students are being given the opportunity to take online courses offered by each of the six institutions. They will achieve ECTS (European credit transfer and accumulation system) through the project.

CONNECT WITH USW:

Professor Andrew Blyth is Director of the Information Security Research Group at the University of South Wales. He specialises in computer forensics and computer network defence, undertaking applied research for industry. For more information, please contact:

andrew.blyth@southwales.ac.uk

or, visit:

security.research.southwales.ac.uk

INDUSTRY INSIGHT:

Cognitive Computing

Computing, Cognition and the Future of Materials Design

BY **COSTAS BEKAS**
IBM RESEARCH-ZURICH

It's not surprising that the public's imagination has been ignited by artificial intelligence since the term was first coined in 1955. In the ensuing 60 years, we have been alternately captivated by its promise, wary of its potential for abuse, and frustrated by its slow development. But like so many advanced technologies that were conceived before their time, artificial intelligence has come to be widely misunderstood: co-opted by Hollywood, mischaracterized by the media, portrayed as everything from saviour to scourge of humanity.

Those of us engaged in serious information science and in its application in the real world of business and society understand the enormous potential of intelligent systems. The future of such technology – which we believe will be cognitive, not "artificial" – has very different characteristics from those generally attributed to AI, spawning different kinds of technological, scientific, and societal challenges and opportunities, with different requirements for governance, policy, and management.

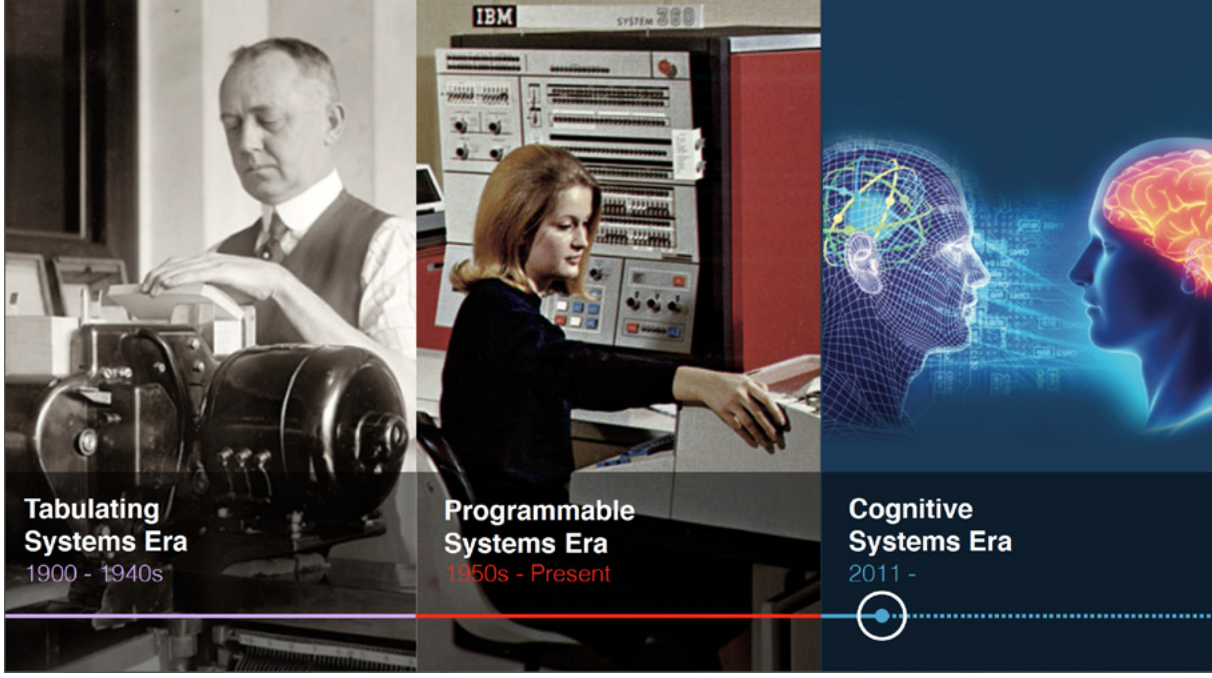
Cognitive computing refers to systems that learn at scale, reason with purpose, and interact with humans naturally. Most important, rather than being explicitly programmed, they learn and reason from their interactions with us and from their experiences with their environment. They are made possible by advances in a number of scientific fields over the past half-century, and are different in important ways from the information systems that preceded them. Those systems have been deterministic; cognitive systems are probabilistic. They generate not just answers to numerical problems, but hypotheses, reasoned arguments, and recommendations about more complex – and meaningful – bodies of data.

What's more, cognitive systems can make sense of the 80 percent of the world's data that computer scientists call "unstructured." This enables them to keep pace with the volume, complexity, and unpredictability of information and systems in the modern world.

None of this involves either sentience or autonomy on the part of machines. Rather, it consists of augmenting the human ability to understand – and act upon – the complex systems of our society. This augmented intelligence is the necessary next step in our ability to harness technology in the pursuit of knowledge, to further our expertise, and to improve the human condition. That is why it represents

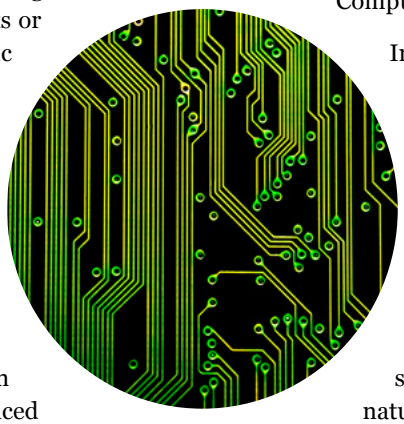
WATSON, An IBM supercomputer developed in collaboration with US university researchers, in 2011 beat long-standing *Jeopardy!* Champions using natural language responses. (Credit: Sony Pictures / IBM)

A HISTORY OF COMPUTING: Enter the post-millenium era of probabilistic, self-reasoning machines.



not just a new technology, but the dawn of a new era of technology, business, and society: *The Cognitive Era*.

The success of cognitive computing will not be measured by Turing tests or a computer's ability to mimic humans. It will be measured in more practical ways, like return on investment, new market opportunities, diseases cured and lives saved. Here at IBM, we have been working on the foundations of cognitive computing technology for decades, combining more than a dozen disciplines of advanced computer science with 100 years of business expertise. Now, we are seeing first-hand its potential to transform businesses, governments, and society. We have seen it turn big data from obstacle to opportunity, help physicians make early diagnoses for childhood disease, and suggest creative solutions for building smarter cities. And we believe that this technology represents our best – perhaps our only – chance to help tackle some of the most enduring systemic issues facing our planet, from cancer to climate change to an increasingly complex global economy.



Cognitive systems for materials design combine, human expertise, Big Data analytics of unstructured and structured data and massive computation. They hold great promise simply because for the first time they allow us to combine and take advantage of all three pillars of discovery: Theory, Experiment and Computation in a uniquely seamless way.

Imagine a computing system that can read huge numbers of papers, patents, scientific and industrial reports. Imagine a system that can attach semantic meaning to scientific figures and read complex chemical formulas. Imagine incorporating all the relations about materials, their uses and the conditions under which materials are useful and how they are manufactured. Imagine a system that allows a materials science expert to be able to pose questions in natural language, using the lingo of the trade, and get back an intelligent answer: "What is a good doping alternative to Copper for my case", and the system to understand what "my case" means. These are characteristics of cognitive systems that we are building at IBM. Our purpose is clear. Augment the expert, free us from the "tyranny" of big data and allow our best qualities to focus on what is most important: creativity.

ABOUT THE AUTHOR:

COSTAS BEKAS *(@CostasBekas)* manages the **Foundations of Cognitive Computing** group at **IBM Research-Zurich**. His main research interests span HPC, massive scale analytics, cognitive computing, and energy aware algorithms and architectures. For collaboration enquiries, contact: *BEK@zurich.ibm.com*

UNIVERSITY HIGHLIGHT:

Sonic Innovations

The next-generation of audible sound; object-based audio broadcasting, audio information mining, and distortion recognition

University of Salford MANCHESTER

AUDIO SOLUTIONS FOR LIVE SPORT BROADCAST

The challenge of creating a live sound mix for a sports event such as a football match cannot be underestimated. The operator of a console has to continually manage the individual feeds from (typically) 12 pitch-side microphones, and microphones for referees and crowd noise.

Skilled mixers are able to do this, but in many territories, the unskilled mixer will typically leave microphones open at a fixed position resulting in very poor broadcast audio mix with excessive crowd noise masking the on-pitch sounds. With the introduction of immersive audio and/or object-based broadcasting, even skilled mixers will find it challenging to manage all the extra mic feeds needed.

Researchers at the University of Salford have developed a new, innovative approach to addressing the problem which they call SALSA (Spatial Automated Live Sport Audio). SALSA takes an object-based approach to solving the problem, and creates an automatic, real time high quality mix. SALSA works by tracking the location of events and therefore the focus on the pitch. This then automatically drives console fader movements, helping to isolate on pitch sounds from crowd noise.

SALSA can also augment on-pitch audio in real time by matching detected sound events to a bank of pre-rendered samples that are triggered based on object metadata, for example - inserting optimal ball 'kick' sounds to improve the viewing experience.

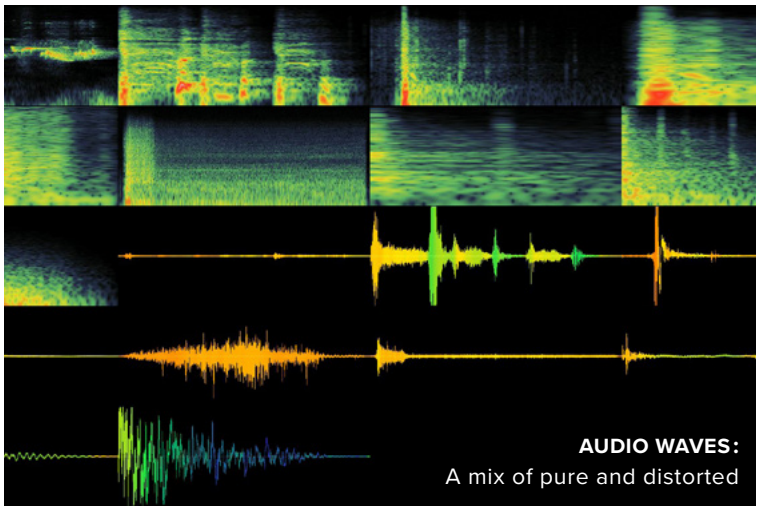
In a collaboration with DTS, Inc. and Fairlight, SALSA has been integrated into a next-gen live production system based on MDA, the open object-based audio standard (ETSI 103-223). It allows for either fully automated or assistive mixing for current and future broadcast systems.

SOCCER CITY, JOHANNESBURG:
Ghana vs. Germany
2010 World Cup

A HISTORY OF AUDIO RESEARCH

Audio research has been conducted at the University of Salford since before 1965. Research is funded by research councils, national and international government bodies, and industry - including major national and international names. Our research has fed into products that companies make and sell worldwide, as well as regulations and standards used in the UK, Europe and internationally.

The depth of research has led to a number of innovative, software-based audio solutions, with applications in a variety of sectors, including live sports broadcast, automated audio quality assessment, and archive management.



AUDIO WAVES:
A mix of pure and distorted

SOLUTIONS FOR EFFICIENT AUDIO ARCHIVING AND SEARCHING

Audio mining is a technique used to search through audio databases' or archives for specific content, such as occurrences of spoken words or phrases. Media archives are continually growing in size, leading to increased demand for automated metadata generation, indexing and searching functionality.

One challenge to current methods of audio mining is classifying recordings that contain overlapping sources of speech, music, event noises or ambient sounds. Machine audition and music information retrieval tools have been developed for specific sound retrieval, but combined use of these systems is poorly developed. Therefore, sources of diverse audio overlap can mitigate the classification of different sound, resulting in poor recognition and/or missing content, and reduce the usability of audio archives.

Salford researchers have developed a tool which enables the classification of different, overlapping sound types from one source track, for more accurate audio information mining. By employing unique iterative signal clearing techniques, this tool is capable of classifying the arbitrary audio signals into music, speech, ambient sounds and silence, whilst providing time-stamp information for each source.

Using this technique can reduce or eliminate information losses embedded in a soundtrack during machine audition and audio retrieval processes, therefore improving their usability and giving significantly more reliable results.

It is an exciting development for the users and developers of audio software; it could improve the usability of audio archive search through the development of an improved sound classification system. It is also able to improve speech recognition software more generally, with applications for speech translation into text over a complex soundscape of background noise.

SOLUTIONS FOR AUDIO QUALITY ASSESSMENT

Distortion of audio is a common problem. Most people will recognise the issue of public address systems (e.g. within train stations) being indecipherable; users of modern, handy recording devices will often find the audio to be poor quality. Of particular concern for audio distortion is User Generated Content (UGC), which is now used extensively in news broadcasting: on average, a news agency adopts 11 pieces of UGC daily.

This issue necessitates a rapid assessment method to determine if the audio quality of UGC is broadcast worthy. In addition, if audio problems can be detected whilst recording, and feedback given to the operator of the device, many disappointing end results could be avoided.

Researchers at the University of Salford have developed a software tool that detects and quantifies the degree of distortion a listener would perceive in an audio file, enabling metadata associated with the quality of the audio file to be generated and acted upon. Uniquely, the software generates results which are perceptually weighted - i.e. the results are relevant to the degree of distortion a real listener would perceive. In addition, the software tool uses a 'single ended' 'blind' assessment so no prior knowledge about the source or reproduction chain is required.

The software tool can be integrated into media asset management systems to enable editors and broadcasters to select media assets with appropriate audio quality for broadcast. It can be similarly integrated into recording devices to dynamically monitor and assess a recording while offering feedback to the operator as to the quality of the recording in real time. In audio systems that commonly suffer distortion problems, such as public address systems and hearing aids, the tool can improve audio quality.

INDUSTRY INSIGHT:

Active Sound Management

Managing total sound environments: A holistic approach to vehicle acoustics

BY **RYAN BOYLE & DAN PIERSON**
Bose Active Sound Management Division

A car's sound is an integral part of its DNA. For sporty vehicles, having an exciting engine note might be as important to a shopper as horsepower ratings. For a luxury buyer, a quiet interior can reinforce the car's value. This subtle but important detail can support the overall perception of quality in a car.

Car manufacturers spend a lot of time engineering their signature in-cabin sound. They focus particular attention on reducing powertrain noises that can be unpleasant to those inside the car. Typically, these noises relate to engine harmonics across the car's RPM range. At certain RPMs and load conditions, for example, a 'boom' might become noticeable and create an undesirable experience.

Traditionally, mechanical countermeasures have been utilized to minimise these problems. Noise mitigation techniques can include damping mats, balancer shafts, and mufflers. While these techniques have been effective, they are often costly, heavy, and can affect a car's development cycle because of the prototyping and tooling time involved in designing these parts. Recently, advances in in-cabin active noise cancellation (ANC) have created a more progressive approach: Use the vehicle's audio system to cancel out these unwanted powertrain noises.

The principle of ANC is well understood, and was pioneered by Bose over 30 years ago. While different from the wide-band cancellation popular in consumer headphones today, the physics of using acoustically opposite signals to cancel tones at a listener's ears is still applied. Bose Engine Harmonic Cancellation (EHC) receives RPM information from the engine, and while being monitored by in-cabin microphones, is able to add tones of the correct magnitude and phase into the Bose entertainment audio speakers to cancel the unwanted engine harmonics. This is done automatically and seamlessly, regardless of whether the sound system is on or off.

SOURCE: *BOSE*

SMOOTH DRIVING: Self-contained acoustic bliss

In many cases, cancelling undesirable noises within the car is not enough. A smooth, consistent sound throughout the RPM range is important, and to help achieve this, Engine Harmonic Enhancement (EHE) is also available from Bose. EHE does not synthesise sounds that are not already present, but instead adds complementary signals to the engine's harmonics depending on the car's targets. Bose works with their auto industry customers very closely, tuning each individual model for maximum performance. Several parameters are considered and adjusted for, including acceleration

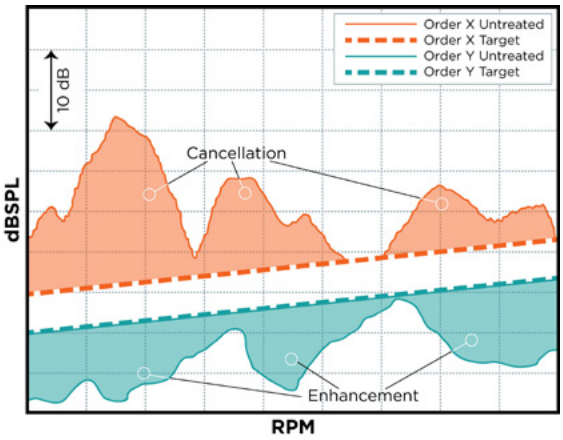


FIGURE 1 : Joint application of Engine Harmonic Cancellation (EHC) and Engine Harmonic Enhancement (EHE) on *multiple orders* across a single rpm range.

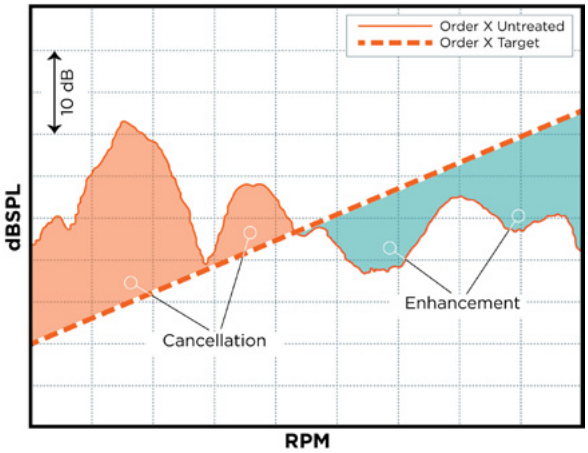


FIGURE 2 : Joint application of Engine Harmonic Cancellation (EHC) and Engine Harmonic Enhancement (EHE) on a *single order* across separate rpm ranges.

or load level, gear shifts, or car specific modes like eco or sport. Using both algorithms in combination provides the ability to boost certain harmonics and reduce others across the same RPM range *(see figure 1)* or to treat one harmonic with cancellation and with enhancement across separate ranges *(see figure 2)*.

A key differentiator that sets Bose apart is their proprietary algorithm that runs the system. Deviations of the acoustical properties in the car cabin may occur due to many factors, such as open windows, aging of components, or production variations in the vehicle. System stability, without a reduction in noise cancelling performance or audible artefacts, is ensured by building in a robust set of tolerance parameters. Another key innovation within the algorithm is the ability to create and control the soundstage of these generated sounds. A natural representation is the ideal result, like enhancement contributions to both the engine sound in front of a listener as well as the exhaust note behind the listener.

EHC and EHE, taken together along with many other tools available to support manufacturers, are key pillars of the Bose Active Sound Management (ASM) portfolio. These technologies are not just concepts. They are available right now and are in production in many cars all over the world. Bose ASM can generally be applied in two scenarios. It can be used to correct issues discovered too late in the development cycle of a vehicle to make major changes. Engineers can count on the flexibility afforded to them by Bose ASM. However, even more gains can be realised earlier in the planning process. Taking ASM capabilities into account starting in the vehicle planning phase may influence design decisions that would normally have to be compromised for negatively impacting sound quality or fuel economy.

As cars face more and more stringent efficiency constraints, EHC and EHE will become a more important tool in building cars that meet that challenge. ASM applications have particular value for many newer powertrain technologies that can improve fuel economy but compromise in other areas, including how it sounds. Cylinder deactivation, downsizing of engines utilising turbochargers, and torque converter lockups are all examples of technologies that could benefit from engine harmonic cancellation and enhancement

Bose Automotive Systems aren't just innovating in entertainment audio. They are using a deep understanding of the physics behind sound to enable car makers to design better cars with fewer compromises.

RYAN BOYLE is Technical Product Marketing Specialist **DAN PIERSON** is a Product Manager. For collaboration enquiries, please contact: *dan_pierson@bose.com*

UNIVERSITY HIGHLIGHT:

Enhancing Human-Computer Interaction

Innovation with users at its heart - towards better information interaction

CITY UNIVERSITY LONDON
EST 1894

AHAMO - A NOVEL LEARNING PLATFORM THAT LEVERAGES USER-GENERATED DATA TO ADVANCE INSIGHTS

The education and learning landscape in the UK is rapidly changing. Online learning now accounts for over 25% of all delivery and is set to accelerate as e-learning tools improve in sophistication and availability. Online solutions increasingly rely on videos to communicate learning material. However, videos present a solitary, passive learning experience and do not support collaborative learning amongst peers. Moreover, for educators, the benefits of videos as a value-add are unclear since only simple analytics are available.

Hub, one of Televisual's top 50 video production companies, are fiercely passionate about not only producing high quality and engaging video, but also driving the industry forward. Recognising a market gap for more engaging learning experiences, they collaborated with the Centre for Human-Computer Interaction Design in a Knowledge Transfer Partnership project to create something truly novel within the space of interactive video.

The Ahamo team

The result was Ahamo - a unique interactive e-learning Software as a Service (SaaS) tool which wraps around existing video content and provides opportunities to reflect, discover and share learned insights with others. Ahamo creates an active learning experience through in-video annotations and uses data science and data visualizations to encourage reflection and leverage peer learning. It thus increases engagement and sense of achievement.

The benefits for educators include the ability to demonstrate and measure use of video for learning within the organisation, as well providing a more engaging enhancement to current learning platforms. Ahamo's design and development was based on core user requirements thorough academic research and deep engagement with users, including a 6-week field trial with a global energy manufacturer.

Investment opportunity: The tool's current state of development is a working prototype. To date the project has received £185,000 of investment and the Ahamo team are currently seeking to raise £250,000 in further investment in return for a 20% equity in preference shares. The investment period is 5 years. An additional round of funding will be sought at the end of Year 2. We would be very keen to hear from any interested investors or collaborators to help us take this unique tool further into the e-learning space.

THE CENTRE FOR HUMAN-COMPUTER INTERACTION DESIGN, CITY UNIVERSITY LONDON:

The Centre for HCI Design focuses on how to create new technology with user experience (UX) in mind, especially novel interactions with information and intelligent systems and devices. Recent work has included: digital therapy tools for people with aphasia - a language disorder commonly experienced after a stroke; a mobile app to improve the passenger journey experience; and a novel interface that uses temperature as a feedback mechanism to the user.

Our location puts us at the heart of the growing technology hub in London and we frequently engage with business - whatever its size. To complement research, we have a state-of-the-art usability lab available as part of our consultancy services. City also offers postgraduate courses at Masters and Research degree levels, including an MSc Human-Computer Interaction Design.

UX RESEARCH,
An observation room looking into the City Interaction Lab

A CLOSER LOOK:

THE CITY INTERACTION LAB - *UX CONSULTANCY*

The City Interaction Lab is the Centre for HCI Design's unique commercial consultancy service which supports businesses with user research, interaction and service design, information architecture, training and usability evaluations.

We have worked with a range of clients, from start-ups to large enterprises, to bring academic research and state-of-the-art processes to industrial clients. Recent work has included: UX training for a major UK charity; gathering user requirements for a social housing mobile application; and usability testing of a Government agency website.

We have been praised for our exceptional value-for-money as well as speed, coupled with highly detailed and insightful documentation that supports actions and implementation.

Lab Hire Basic - includes use of small observation room From £500; Lab Hire Premium - includes use of large observation room, From £700; Consultancy day rates, From £200 per day. For further information about the City Interaction Lab and our pricing, contact Stuart Scott at: *stuart.scott.2@city.ac.uk*, or: *0207 040 3087*

> "I'd recommend them to anyone looking to make sure that their users are at the heart of what they do.
>
> - Cancer Research UK

KEY COLLABORATORS:

DR GEORGE BUCHANAN is the Director of the Centre for HCI Design. His research interests surround information interaction through searching on the web, browsing digital libraries or mobile information access.

Tel: *+44 (0) 20 7040 8469*
Email: *george.buchanan.1@city.ac.uk*
Twitter: *@GeorgeRBuchanan*

DR SIMONE STUMPF is a Senior Lecturer in the Centre for HCI Design. Her core research focus areas are the use of intelligent systems by end users, end-user programming and personal information management systems.

Tel: *+44 (0) 20 7040 8168*
Email: *simone.stumpf.1@city.ac.uk*
Twitter: *@drsimonestumpf*

STUART SCOTT is the manager of City Interaction Lab where he supports commercial clients via UX consultancy. Stuart is adept at simplifying complicated user experiences through the application of best practices in interaction design. This is reinforced by his practical knowledge of web technologies.

Tel: *+44 (0) 20 7040 3087*
Email: *Stuart.Scott.2@city.ac.uk*
Twitter: *@cinteractionlab*

DAVID HUNSTONE is the founder and Managing Director of Hub. David has been pushing the creative possibilities of video and short film for over a decade, inspiring brands and businesses to find their voice through moving pictures. Hub is now ranked as one of Televisual's top 50 video production companies.

Contact www.hub.tv for more information.

IN-PART

Searching for advances in university research for collaboration & co-development?

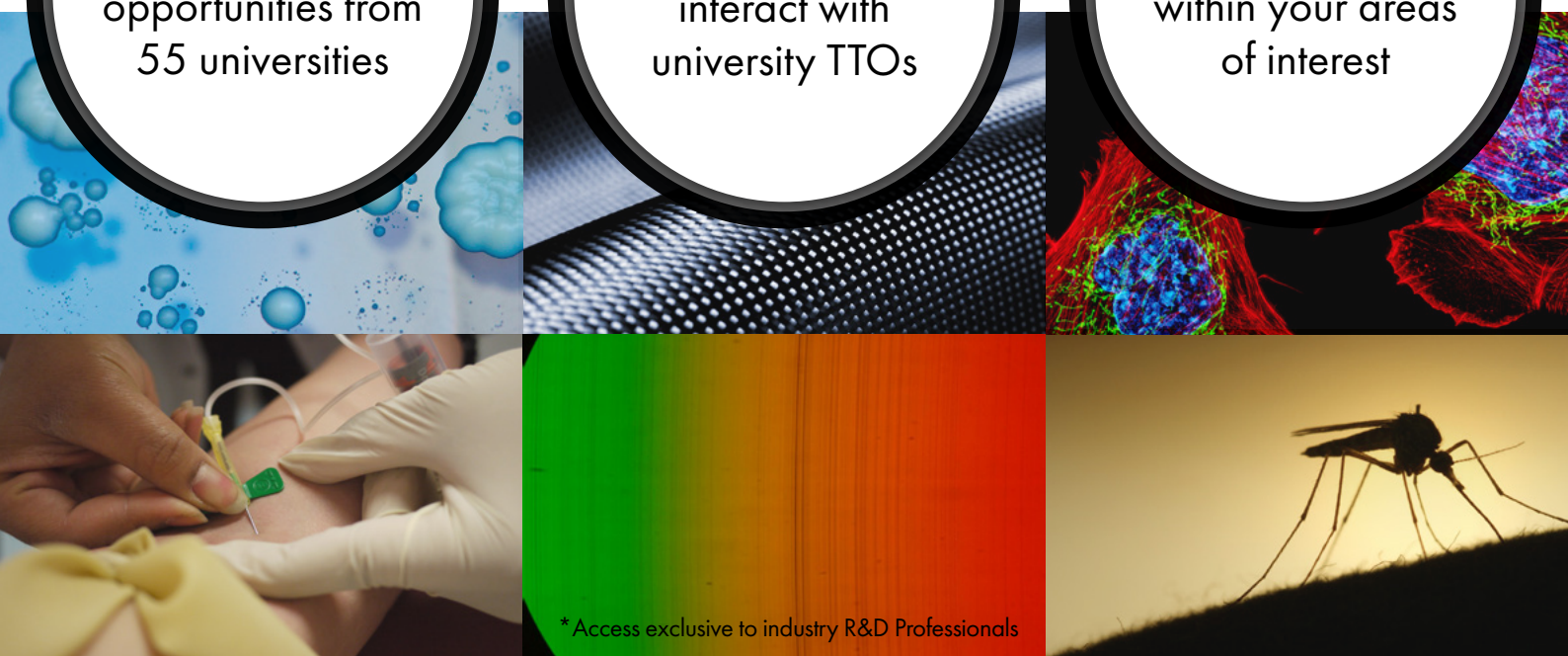
IN-PART is a mind-store of innovation from the frontiers of bioscience, technology, and engineering, all seeking collaborative partnerships with businesses

Register at in-part.com for free access* to:

Exclusive collaboration opportunities from 55 universities

A facility to connect and interact with university TTOs

Alerts for new opportunities within your areas of interest



*Access exclusive to industry R&D Professionals