Institution: University of Bedfordshire

Unit of assessment: UoA11 Computer Science and Informatics

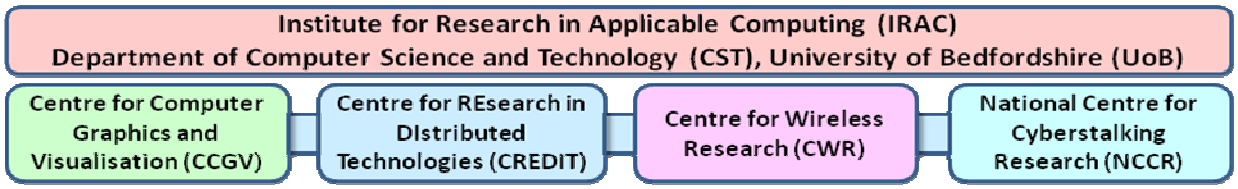
a. Overview of the Institute for Research in Applicable Computing

The *Institute for Research in Applicable Computing (IRAC)* develops novel computer technology and related applications and electronics to solve real-world problems that have social and economic impact at the local, national and international level, as well as innovative tools to enable users to employ computer technology more efficiently and effectively. IRAC, founded in 2003, is one of the University of Bedfordshire's (UoB) ten research institutes, supporting UoB's research strategy to move from a teaching-led to a teaching-and-research-led institution. UoB provides infrastructure and strategic growth funding to IRAC. Further funding is obtained from UK Research Councils, the Royal Academy of Engineering, the European Commission, the UK Government, industry and various other European and international agencies. IRAC is overseen by a strategic Steering Group, supported by the Institute Board, including representatives of staff groups (academic and full-time research) and research students.

As a result of considerable investment by the UoB since RAE 2008, IRAC has prospered not just in size and income, but also in terms of quality outputs. The institute has also been, expanded into special purpose modern surroundings. These figures tell the story: in 2008, IRAC published 20 journal papers, had 20 academics and 35 research students, whereas in 2013, there were more than 60 journal papers, 46 academics and 90 research students. Total research income (including from research student fees) has risen from £1.2 million to £1.4 million in 2012/13.

All research-active members of the Department of Computer Science and Technology (CST) are members of IRAC. Membership is also open to researchers across the University, thus encouraging multi- and inter-disciplinary work.

The Director of Institute is Prof. Edmond Prakash, who has led world-wide research. IRAC has four established specialist centres, each with its own head, supported by a deputy head for continuity:



- *Centre for Computer Graphics and Visualisation (CCGV)*, Head Prof. Gordon Clapworthy, with five main activity areas, including interactive multi-scale visualisation in biomedicine
- *Centre for Research in Distributed Technologies (CREDIT)*, Head Dr. Dayou Li, with four main activity areas, including autonomous robots for helping the elderly
- *Centre for Wireless Research (CWR)*, Head Professor Ben Allen, with two groups each with three activity areas, including wireless technologies and energy efficient electronic devices
- *National Centre for Cyberstalking Research (NCCR)*, co-Directors Prof. Carsten Maple and Dr. Emma Short (from Psychology), with activities in pro- and re-active responses to cyberstalking.

In September 2013, UoB opened the new University Campus Milton Keynes, extending IRAC's research activity with the nascent *Centre for Autonomous Systems and Robotics for Future Cities*.

b. Research strategy

Period since RAE2008

The five strategic strands identified in RAE 2008 have developed considerably and show the Institute's resilience in a rapidly changing environment.

1) General consolidation: From 2008 to 2013, IRAC tripled the number of journal papers published per annum, more than doubled academic (including research) staff (25 to 66), and more than doubled research student numbers. The institute has increased its physical accommodation proportionately, as well as enhancing its infrastructure.

2) Centres' technical thrust: In 2008 there were three centres; there are now four established ones. CREDIT, whilst previously having a focus on computer networking and security, now focuses

activity towards intelligent biomedical/bioinformatics systems. The new centre, NCCR, which started in Sept 2010, has taken forward those aspects relating to systematic criminal/maleficent computer-assisted attacks to develop the new cyberstalking speciality. One centre, CWiND (Centre for Wireless Network Design), together with its principal lead, moved to the University of Sheffield in 2011; however, the continuing commercial and technical relevance of wireless technology remain critical to the reorganised centre, CWR, which replaced it. The anticipated expansion of Virtual Physiological Human research was fully realised and it provided a variety of opportunities for CCGV to extend its previous work in biomedical applications beyond musculoskeletal applications into areas such as cancer, heart failure, osteoporosis, ophthalmology and conditions induced by multiple morbidities.

3) Continued improvements in

- *quality of outputs*: moving in general from submission of papers at conferences to quality journals (based on ranking in discipline) and more established conferences, as well as patents;
- *effective use of energy and expertise of recently arrived postdocs*: enabling postdocs to have time to commit both to IRAC projects and to extending their own personal areas of interest;
- *timely research student thesis submission*: improved central and institute research programme monitoring and management;
- *monitoring demands on key researchers to avoid over-stretch*: promotions to more research-focused roles, including Reader; use of research overheads to enable further research time.

4) Funding stream diversification: At RAE2008, IRAC was considered a little over-reliant on EC funding. Now a wider range of funding is accessed, with each centre having its own strategy as outlined in section d.

5) Collaboration: was then, and continues to be, a major feature of the Institute. At 2008, EC funding provided opportunities to forge links with strong partners in Europe and further successful proposals involving these partners have underlined the ongoing nature of the relationships. CCGV and CWiND each developed links with top research laboratories in their fields in China; CCGV's plans have deepened and extended these relationships significantly.

Vision and Strategy

IRAC's vision is to be beyond world-leading recognised and respected as a centre of excellence and significance in applicable computing by developing innovative applications of research and expertise, and forming successful partnerships for social, cultural and economic development across the health, energy, security and assisted living sectors and communities.

The strategic position is fully in line with the wider strategy of the University. The strategic objectives – developed from review of internal and external opportunities and constraints – to implement this vision are to:

- Enhance the impact, exploitation and reach of the research, through being a recognised provider of client-led enterprise and innovation to industry and government agencies.
- Expand the client and funding bases with the ability to deliver timely and bespoke responses, both in technology and in the provision of services.
- Generate new areas of inter-disciplinary research expertise responsive to the global challenges of social and demographic change, economic competition and the sustainable development of organisations, communities and societies.
- Increase the links with industry with regard to understanding its requirements for research.
- Increase the number and effectiveness of staff who are research and/or enterprise active.
- Develop effective working at all levels with the University Campus Milton Keynes to enable an expansion of the IRAC research strands, impact and associated reach into the community.
- Propose and implement targeted financial investment to support and enable an increase in the number and effectiveness of research students; a wider strategic reach of IRAC into the community; and an increase in IRAC's reputation, both nationally and internationally.

c. People:

i. Staffing strategy and staff development

IRAC

The IRAC directorship is held on a rotational basis to ensure centre heads and others can

experience this leadership role. All Centres have a deputy head to ensure continuity and support career development.

Recruitment to the University is in the first instance to the CST Department, in line with university-wide policies, including equality and diversity. Attracting female staff remains a priority in the disciplines of computer science and technology, While still low in absolute terms, the team are pleased that after only one female staff was submitted to RAE2008, seven female staff form part of this submission. Female and male staff members have been supported during maternity/paternity. Disability issues such as dyslexia and long-term illness are appropriately recognised and managed with the staff concerned. For research staff recruitment and skill development at IRAC, UoB has a university-wide policy that follows national principles: QAA Code of Practice and HR Excellence in Research. In May 2013, UoB's institution-wide Concordat implementation plan was awarded the European Commission's HR Excellence in Research Award, which will be rolled out in the coming period.

Recruit, Retain & Nurture: UoB has a successful policy of recruiting, retaining and nurturing of staff as the cornerstone of its sustainable staffing strategy, i.e.:

(1) **Recruit**: The CST Department actively recruits excellent researchers who successfully contribute to the development agenda. New professors have been recruited to lead the development of new areas of research in applicable computing.
(2) **Retain**: To retain research staff, UoB operates an annual promotion scheme that recognises and rewards excellence.
(3) **Nurture**: The University provides centralised support for individuals to access funding information, bid for funding, secure funding and successfully manage and deliver excellent research. Talented individuals nurtured at UoB develop research careers here and are able to pursue research careers elsewhere, including leading research groups at other universities, for example, Prof Zhang built a successful research programme at UoB and is now at the University of Sheffield; Dr Bessis became Professor after joining the University of Derby. Not only have our staff been recognised elsewhere as Professors, they continue to collaborate with UoB and help to deliver excellent research to the UK and beyond.

Research Staff Recruitment and Skills Development for Researchers:

Specific programmes for research skills development are:

- **Quality Research:** IRAC has received QR money for research and researcher development each year since 2009/10, and in 2013/14 has over £200,000 from this source to invest in staff.
- **Seed Funding:** UoB provides seed funding to initiate research activities across the university through a competitive bidding process. This helps staff establish collaborative partnerships and also build on their initial research to successfully bid for further external funding.
- **Rising Stars Funding:** Since 2011, 10 IRAC staff have benefited from UoB's Rising Stars programme, which identifies early career researchers who show promise of excellence in research and supports them with a long term view of demonstrating international excellence.
- **Conference funding:** IRAC, through QR funding, supports staff members to participate in top-tier national and international conferences, to enable effective dissemination of findings, ensure targeted impact, form new collaborations and develop existing ones. This funding is in addition to support within externally funded projects.
- **UoB Conference:** IRAC researchers of all levels present posters and research presentations.
- **IRAC "Away Day":** is held annually to support researcher skills development.
- **Visiting Professors:** IRAC now attracts around 10 visiting professors per year who are distinguished top-tier researchers. This helps staff and student development in IRAC by close interaction with these visitors. Faculty members also visit top-tier research institutes nationally and internationally, assisting staff development and bringing new knowledge back to IRAC.
- **Funding Bid Preparation Workshop:** UoB workshops on successful bid-writing targeting specific funding bodies are run regularly covering: selection of the right funding body and calls to apply for, how to use the Full Economic Costing, reviewing previous bids for lessons learnt and best practice; the workshops use live bids to show the process. IRAC's Prof Clapworthy, who has more than 20 successful EC bids, regularly shares his expertise in bid development.
- **Coaches/Mentors/Buddies:** UoB systematically ensures all senior researchers are engaged in mentoring and developing early career researchers, and are themselves mentored.

- **Research student supervision preparation:** Early career research staff without supervision experience are included in teams to upskill them.
- **Research Fellows and Progression:** IRAC continually has 10 or more RFs supported by research grants, who contribute to research projects. RFs at the end of their contracts frequently take up challenging roles in top organisations, for example, Dr Glazunov, a Marie Curie Research Fellow at IRAC, is now an Engineering Scientist at Kungliga Tekniska Högskolan (Royal Institute of Technology) Stockholm.
- **Doctoral progression:** Four UoB PhD graduates now work in the Department of Computer Science and Technology, and one in central project management roles. Dr Hamid is an RF progressed from IRAC doctoral student. Dr Lopez-Perez is a Member of Technical Staff at the Department of Autonomous Networks and System Research at Bell Laboratories, Alcatel-Lucent, Dublin, Ireland. Dr Lai is Head of the Radio Propagation Team at Ranplan Wireless Network Design Ltd; he was an IRAC PhD student.
- **Early Career Researchers:** IRAC has 25 academics who began their lecturing careers during this assessment period. IRAC supports all ECRs by providing mentors, encouraging collaborative research through bids and outputs and support with to their teaching load. Recruitment and development of ECRs bring vitality to the environment to ensure sustainable growth and are an important part of the strategy.

***CCGV*:** Staffing strategy is well-established and is orientated towards post-docs as the work is project-based, so timescales, content and workload are not well suited to PhD recruitment and programme support costs. Long-term partnerships have developed a consistent funding stream for this model. The creation of a deputy head role serves to ensure continuity in preparation for the current Head's retirement. Where possible, QR money enables buy out of researcher time, so they can follow their particular research interests outside the work on research contracts. Two researchers have received Rising Stars money and two projects, including one with Moorfields Eye Hospital, were funded from UoB sources. The Centre supports one professor in China. As CCGV's staff are 80% international, regular supported writing and cultural sessions are held. Visiting staff contribute regular talks towards staff development.

***CREDIT*:** has a diverse internal structure, with several themes, and three groups. Consequently, staffing strategy covers a wide range of full- and part-time, senior and junior, internal and visiting staff, including additional research fellows for particular specialisms.

***CWR*:** is a new centre, and is developing its staffing strategy to support the lines of work in progress. As with CREDIT, this involves a balanced mix of different roles.

***NCCR*:** has built a multidisciplinary team, including practising barristers as visiting fellows, and research students with backgrounds in technology, victim support, and citizen engagement.

ii. Research students

Postgraduate research student income has increased from £150,000 in 2008 to £360,000 in 2012. Each student has a supervisory team of two supervisors, at least one of whom must have successfully led a student to completion. Where appropriate, students may also have an industry expert on their team, and/or a third supervisor who brings particular specialist knowledge. Student progress is monitored by the supervisory team, IRAC and RGS. At around four months, the proposed research programme is formally assessed by internal reviewers. Between months twelve and sixteen, the student presents a report which has to be approved by two internal reviewers, and a successful open seminar on their research to enable transfer/progress to the PhD stage. All full-time students are allotted office space and computing facilities in one of IRAC's research labs. Part-time students have hot-desking provision.

IRAC research students Ming and Shah have received best paper awards at leading international conferences. Liu et al.'s paper 'Fuzzy Optimisation Based Symbolic Grounding for Service Robots' became a best paper finalist in the prestigious IROS (Intelligent Robots and Systems) conference.

UoB research students self-organise the Research Students Support Group (RSSG) to provide a forum for discussion of academic, social and administrative matters of interest relating to research students. IRAC students are encouraged to develop their own networks and social events. The IRAC Board includes a student representative.

Particular features to support research students:

- **UoB-wide provision:** All research students are supported by the Research Graduate School (RGS). RGS provides support during the application phase, admission stage, registration and induction. RGS then takes the students through the various stages of progression, followed by thesis submission, viva and award of the degrees. Several mandatory and optional research skills training courses are conducted for the research students throughout their time at UoB, including some online licensed packages.
- **IRAC provision:** IRAC inducts students directly into the Institute. At IRAC, students are given support for research proposal development for their PhD study.
- **External conferences:** Research students are expected, as part of their research programme requirements, to present papers to at least one national and one international conference.
- **External event funding:** Students may apply for funding (fees, travel, subsistence) to attend other events, where judged appropriate to their research.
- **Contact-building:** Students are encouraged to attend events (e.g. local authority, government) with staff to meet other professionals.
- **UoB Conference:** Doctoral students are expected as part of their research training requirements to present a poster to at least one UoB conference, and in most cases, to two; this includes part-time students.
- **Internal events:** Students participate in a variety of events, from large, institute-wide colloquia to small, centre or team-based activities and presentations.
- **Research demonstrator programme:** IRAC has started a programme in which 4 demonstrators of the undergraduate labs pursue a part-time PhD programme. Several other technical/lab staff are also PT research students.
- **Faculty bursaries:** The Faculty of Creative Arts, Technologies and Science provides bursary support for outstanding undergraduate students to enter postgraduate research programmes.
- **Careers panel:** A subject specific panel on PhD career choices is organised by IRAC for research students.
- **IRAC "Away Day":** is held annually to support researcher skills development; research students are encouraged to attend.
- **Equality and Diversity:** IRAC recruits internationally, over 50% of students are from UK and the rest are international students.

d. Income, infrastructure and facilities

IRAC

Income: At RAE 2008, IRAC received £1 million external research funding in total, which continues to 2012/13, out of which HEFCE funding is £0.2 million. The centre-based sections below indicate how this money is spent. The University encourages all institutes actively to seek funding opportunities.

Infrastructure and facilities: IRAC infrastructure is managed by the Director of Institute and supported by the Deputy Director and dedicated administrative staff. The infrastructure supports in the bidding process, starting projects. Systems are in place for handling data specific to projects. Published output and data are managed through central University repositories. Secure systems are in place and managed for commercial projects as well as data sensitive projects. Access to the infrastructure is applied consistently for both Institute users and visitors and external users. The Institute is currently reviewing its provision for supporting high sensitivity projects. Ethical, Environmental and Regulatory procedures are followed. IRAC has the following research facilities:

- Four researcher labs – for CCGV, CWR, Robotics – containing workstations for around 100 researchers (students and RFs). The workspaces have been refurbished with £50K. Research equipment has been added, including a high-performance computer cluster from externally funded projects.
- Specialised software such as graphics tools and libraries are available for all researchers. IRAC has a significant MATLAB investment, and obtains a 25% discount on software and tutorials.
- IEEE Xplore and ACM Digital Library – full access.

CCGV

Income: Towards the end of the previous RAE period, CCGV acted as Project Coordinator of the FP6 project STEP which produced a Roadmap introducing the concept of the Virtual Physiological Human – a multi-scale integrative approach to biomedical problems that will ultimately lead to personalised medicine; VPH subsequently became a priority of the ICT Programme of FP7. CCGV has continued to have an extensive involvement with VPH during the current REF period, being a partner in 12 VPH-related projects overall. Funding was also obtained from EPSRC for 2 projects and from the Future and Emerging Technologies (FET), Marie Curie and other EC Programmes for 5 further projects; overall, 7 of the projects had CCGV as Project Coordinator. The total income generated for CCGV from the projects mentioned is over £4M; some projects continue until 2017.

Infrastructure and facilities: The lab was purpose built in 2009, with workstations of the kind, end users of the technologies being developed will use, including specialist NVIDIA GPU cards. There is also a GPU cluster and a local cloud. Overall, capital costs are low. CCGV maintains its own specialist library.

CREDIT

Income: Four EC-funded projects are currently running in AI and robotics, one of which is coordinated by the Centre. EPSRC provides 2 CASE studentships. Other funding comes from the Leverhulme Trust.

Infrastructure and facilities: Recently acquired facilities reflecting the changed focus of CREDIT include: 2 small industrial robot arms, 1 Turtlebot, 2 Hiteck robots and 2 high-spec PCs. The centre has designed and constructed its own robot head with vision, communication and emotion expression. The centre also has a smart chair directly related to current research in assisted standing and sitting for well-being. Through one of the PhDs, it is developing open source software (Robotic Operating System, ROS).

CWR

Income: CWR income includes: research project funding from the public sector; research student fees, including private sector support for part-time industry-led research, public sector support for a student bursary; internal research funding. A repository of radio propagation data (0.5TB) is an asset for future income development.

Infrastructure and facilities: CWR is host to the co-funded Rohde and Schwarz Telecommunications Laboratory and electronics workshop that offers state-of-the-art facilities for design, prototyping, construction and testing of analogue and digital circuits, antennas and wireless communication systems. These laboratories are well equipped with a wide range of world-class design and measurement tools including modelling and simulation software, experimental software defined radio platforms, 60GHz radio experimental platform, RF-over-fibre communications system, wireless sensors and antennas, spectrum analysers, signal generators, vector network analysers and PCB engraver. The CWR has recently upgraded its antenna design and fabrication facilities by investing in state-of-the-art computing resources and electromagnetic simulators. The facilities are supported by highly experienced UoB ICT and technical support teams. Our facilities enable the design, simulation, construction and validation of radio frequency circuits operating up to 6GHz. These include:

- Design and Simulation: National Instruments Multisim, CST electromagnetic simulation software, National Instruments Labview.
- Construction: Rapid prototyping facilities for RF circuits and antennas through the use of a PCB grinder and related design software.
- Validation: State-of-the art radio frequency measurement and testing facilities, including digital modulation / demodulation / analysis, spectrum analysers and network analysers.

CWR also manages over 0.5 terabytes of wireless channel measurements that provide a comprehensive assessment applicable to several emerging wireless systems.

NCCR

Income: Funding currently comes from National Stalking Helpline, EU bids, Nominet funding, Leverhulme Trust, Nuffield Foundation, Research Councils (EPSRC, ESRC), charitable bodies (e.g. Comic Relief), consultation fees.

Infrastructure and facilities: The nature of NCCR's work means it does not require specialist

infrastructure and facilities beyond the standard provision of offices and computational facilities.

e. Collaboration and contribution to the discipline or research base

IRAC

Contribution through Research Workshops, Conferences and Journals: IRAC has initiated and led over 10 research workshops and conferences since 2008, including Parallel Computing in Electronics, April 2011; SWICOM 2012 & 2013; SRS Workshop, Nov 2012; NHDM, Nov 2012, OPTnet 2011, 2012. Prof Maple gave several keynote talks; Prof Allen at LAPC; Prof Prakash delivered keynote at CGAT, Singapore. IRAC researchers are on editorial boards of leading journals. They also edit journal special issues such as IEEE TETC on MMOG Technology; IET Communications on Microwaves, Antennas and Propagation and IJCAT special issue on Computational Optimisation and Engineering Applications.

Contribution through Exchange Visits: IRAC supported the external visits of Prof Allen to the University of Canterbury, New Zealand, Prof Yan to MIT, Prof Prakash to Singapore and Colombia. IRAC has had several incoming visitors. As part of the LaserNami project a delegation led by the VC of Changchun University of Science and Technology, China, visited our VC and IRAC. Prof. Arya, Carleton, Canada helped lead research in Digital Media during his sabbatical here. Prof Becerikli of Kocaeli University, Turkey spent his sabbatical at IRAC and introduced advanced optimisation techniques to researchers.

National Links: UoB is working with the University of Oxford on an EPSRC grant with Dr Waharte as co-investigator on the Unmanned Aircraft project. Several EU projects are ongoing with the University of Sheffield (Prof Zhang). Prof Allen was joint supervisor of a doctoral candidate at the University of Oxford. Prof Bessis from the University of Derby supervises PhD students in IRAC. IRAC works on a 3D-Eye project with Dr Saleh from Moorfields Eye Hospital to develop new techniques to enable clinicians perform eye surgery; and with Dr Tennant, University of Sheffield on novel radio transmission schemes; Dr Green, University of Manchester on the joint SWICOM / ARRS workshop.

Transnational Links: UoB and Technische Universität München (TUM), Germany collaborate on developing a Novel Computing Hardware Architecture. IRAC works with several institutions in China, for example, the Nanotechnology Centre is a joint research centre established between UoB and Changchun University, China. IRAC collaborates with Nanyang Technological University Singapore on smart wireless communications, such as cognitive radio, software defined radio, MIMO and smart antennas. Prof Allen is a Visiting Erskine Fellow at the University of Canterbury, New Zealand. Prof Prakash is a visiting professor at Universidad Pontificia Javerinia, Cali, Colombia. IRAC hosted Prof Arya (Carlton, Canada) for his sabbatical.

Distinguished Speaker Series: UoB, including direct contributions from IRAC, runs a regular seminar series for distinguished speakers from top universities including Oxford, Cambridge, the Wireless Research Centre, University of Canterbury in New Zealand and Vermont University, USA. These seminars promote opportunities to network with expert colleagues, and for research students to become immersed in a rich research-focus environment.

CCGV

Collaborations in Academia, Government and Industry

CCGV has a long history of international and interdisciplinary collaboration and has active collaboration with researchers in more than 20 countries. It has had formal links with the State Key Lab of CAD and Computer Graphics at Zhejiang University, the foremost computer graphics laboratory in China, for more than 10 years. SKL staff have regularly worked at CCGV on funded projects before returning to Zhejiang, and there are regular reciprocal visits. Collaboration is an integral part of EC projects, and CCGV collaborators have included research institutions (e.g. EBI, INRIA), health providers (e.g. Moorfields, Charité in Berlin), supercomputer centres (e.g. CINECA), multinationals (e.g. Philips), high-tech companies (e.g. Ansys, Kitware) and SMEs. CCGV has collaborated with 14 of the THES World's Top 100 Universities in the current period, including Oxford, UCL, ETHZ, EPFL and Stanford. CCGV partners with institutions in Italy, France, Greece, Spain and the UK on the EU's Real Time Simulation for Safer vascular Stenting (RT3S) project.

Contribution to the Discipline

CCGV has made a fundamental contribution to the VPH priority of the EC. Software developed by

CCGV is part of the open source VPH Toolkit which is gathering a range of compatible software from many sources to support ongoing biomedical research. In one aspect of this, CCGV was a founding partner in the development of MAF, which is an open source platform for the rapid development of biomedical software and is the software on which many of the VPH projects have been based. In addition to the specialised visualisation software in MAF, CCGV developed the novel VTK-compliant data structures that are used for effective data storage within MAF; these support efficient out-of-core volume and surface visualisation. Based on MAF, CCGV developed the first approach to visualising multi-scale biomedical data. The "click-and-zoom" interaction developed proved effective and this has now been extended to the "VTK buttons" which support the fundamental interactions within the MSVTK toolkit released in 2013. MSVTK was developed, in collaboration with Kitware, within the MSV project (FP7-248032) and is the first such product to support multi-scale visualisation. MSVTK is distributed by Kitware alongside VTK, the Visualization Toolkit, which is widely used in a range of scientific and technological applications.

CCGV has also developed a range of fundamental GPU-based algorithms which are the fastest yet published. These have focused on medical visualisation, particularly ray tracing, isosurface rendering and centreline extraction. The small memory footprint of the accelerating structures means that data files previously too large to fit into GPU memory can now be rendered rapidly on a single GPU. The methods are also scalable to multiple GPUs. CCGV members have published over 40 journal papers in the current period, with the main targets being leading computer graphics journals such as IEEE Transactions in Visualization and Computer Graphics and Computer Graphics Forum.

CREDIT

Collaborations in Academia, Government and Industry

CREDIT currently leads three joint research centres: with the Joint Centre for Computer-controlled Nano-manufacturing, CREDIT collaborates with Changchun University of Science and Technology; with the High-performance Computer Joint Research Centre, CREDIT collaborates with Cambridge, Imperial, and IBM; the Autonomous and Robotic Technique Joint Research Centre, CREDIT collaborates with Milton Keynes City Council, and the Universities of Bournemouth, Cardiff and Essex.

Through joint research and the EU robotics projects, CREDIT has established strong connections with research institutions, universities and industry in the UK, European countries, China, Japan and the USA, including 19 research institutions and industrial companies in Europe and 8 research institutions in China.

The nascent Centre for Autonomous Systems and Robotics for Future Cities in the new University Campus Milton Keynes will be a collaboration with Milton Keynes City Council, BT, Diol and E-on.

Contribution to the Discipline

In cryptography, Prof Song was invited by Harvard University, Beijing University and Hong Kong University to undertake short research sabbaticals at their respective institutions. Members of the Centre have published more than 50 high-quality research papers in the last 5 years in top-ranking journals and conferences, including IEEE Transactions, Applied Soft Computing, Expert Systems with Applications and the International Conference on Intelligent Robots and Systems.

CWR

Collaborations in Academia, Government and Industry

Since the CWinD to CWR transformation in January 2011, the centre has made several recognised contributions. For example, in radio frequency energy harvesting, a recent innovation resulted in filing two patents and has subsequently attracted significant international media coverage. The CWR also values a number of notable collaborations with private, public sector and academic partners that contributed to the growing reputation of the CWR. These include the University of Canterbury, New Zealand; University of Oxford, HMGCC, AND Technology Research, RANPLAN, INSA Lyon, University of Sheffield, the Royal Institute of Technology, Sweden, GCHQ, and ABB.

Dr Zhang won the Royal Academy of Engineering's Industrial Secondment Scheme Award, which includes an award to UoB, providing an invaluable opportunity for an engineering academic to gain industrial experience on a one-year secondment with Aeroflex International Ltd., internationally renowned in the development of electronic technology. Zhang's secondment involved development

of next-generation wireless systems potentially leading to a new product line as a direct result of this collaborative research. Dr Karadimas conducted primary research at the University of Oxford. Prof Allen co-supervised a DPhil student at the University of Oxford.

Contribution to the Discipline

Prior to January 2011, CWiND enjoyed numerous successes in the area of wireless network planning, and as a result attracted considerable income from public and private sector organisations. Of particular note are participation in EC funded projects GAWIND, RANPLAN and iPLAN, which provided a platform for rich collaboration and technical achievement. Two EC Marie Curie grants enabled Research Fellows, Drs de la Roche and Glazunov, to make major contributions in the area of radio wave propagation for small-cell mobile networks; this led to them teaming up with Prof Allen to publish the edited book "LTE-Advanced and Next Generation Wireless Networks: Channel Modelling and propagation". The activity brought together leading researchers from across the world to contribute to the book, including two members of CWR who contributed key chapters.

Prof Allen is on the Editorial Board of IET Journal of Microwaves, Antennas and Propagation and on the Advisory Board for Biztech, a regional forum for promising technology-related business. He was guest editor for a special issue of IET Microwave, Antennas and Propagation Journal. Two members are IET Fellows.

NCCR

Collaborations in Academia, Government and Industry

The centre has concentrated partnerships with impact users to ensure the relevance of the research undertaken and application of its findings. Research in NCCR led to the co-ordination of National Stalking Awareness Day (NSAD) 2012 in collaboration with the National Stalking Helpline, and hosted an event at the House of Lords. NSAD raised awareness of the issues around stalking and the growing problem of cyberstalking. Other sponsors included the Association of Chief Police Officers Working Group on Stalking and Harassment, NAPO – the Probation Service union, and 3 support charities. It was coordinated with a similar event at Holyrood Palace, Edinburgh, organised by Action Scotland Against Stalking. Prof Maple (NCCR co-director) spoke about the work undertaken to provide help to the victims of stalking and further steps to be accomplished to increase awareness, develop training programmes within police units working with the College of Police, provide advocacy services and shape the law – all aimed at ensuring that victims of stalking and cyberstalking receive the well-coordinated support and justice they deserve. The Centre has a number of visiting fellows from academia, including in Australia, and members have spoken at or visited universities such as Nantong, UCL, Cambridge, Oxford, and TUM.

Contribution to the Discipline

The development of the NCCR itself grew out of UoB research and a recognition that there was a significant gap in research in the topic of cyberstalking. Since then, NCCR has contributed case studies that influence public policy, including "Vulnerability, Victims and Free Movement: the Case of Cyberstalking" and "Cyberstalking in the UK: Analysis and Recommendations". The Centre advised the Equality and Human Rights Commission and also the National Police Improvement Agency on an e-learning package for police forces. The Centre spoke about cyber stalking at training events for West Mercia Police and for Thames Valley Probation Services in April, 2012. The Centre took part in the Home Office Road Show, a series of events run by the Home Office that delivered training workshops to the police and allied services information about stalking and cyberstalking. The Electronic Communication Harassment Observation (ECHO) pilot study was launched on 11 April 2011 to coincide with the launch of Out of the Shadows: National Stalking Awareness Week. An active research link with the UoB Psychology department is developing new policies to support cyberstalking victims and law enforcement. The Centre also includes external visiting fellows, such as barristers, and experts in forensic investigation.

NCCR Head is part of: BCS Elite, FBCS, BCS Security Community of Expertise, ACPO Working Group (as is the NCCR Co-director) and an IAAC member. He has been an invited speaker at the Royal College of Psychologists AGM and the Inner Temple (significant because judges play an important role in countering cyberstalking), and keynote speaker at numerous international research conferences.