Institution: Queen's University Belfast

Unit of Assessment: 11

a. Overview

The Computer Science UoA at Queen's University Belfast is part of the School of Electronics, Electrical Engineering and Computer Science (EEECS) (www.qub.ac.uk/schools/eeecs) which was created in 2005 and covers UoA11 and UoA13. The Head of School is Professor Scott (UoA11). Queen's University has been one of the pioneers in recognising the need to integrate the converging technologies of electronics and information technology, and in creating and supporting the large scale organisational structures to make this integration a reality.

Research within UoA11 has been focused into three research clusters. Each research cluster is a University-recognised managerial entity, and is led by a Director of Research.

(i)   **High performance and Distributed Computing** (HPDC, under Prof Nikolopoulos)

(ii)   **Knowledge and Data Engineering** (KDE, under Prof Liu)

(iii) **Speech, Image and Visions Systems** (SIVS, under Prof Crookes), which is based, along with selected research clusters from EEE, at the Institute of Electronics, Communications and Information Technology (ECIT) (www.ecit.qub.ac.uk) in the Northern Ireland Science Park.

Since RAE 2008, the UoA has been closely involved in the creation of the new £30M national Centre for Secure Information Technologies (CSIT), the UK's major innovation and knowledge centre based at ECIT providing research and technology transfer for security, both physical and electronic (www.csit.qub.ac.uk). Two of the unit's clusters in particular (SIVS and KDE) have been intimately involved in driving CSIT's research agenda in intelligent video surveillance and several aspects of data and network security. CSIT is located at ECIT. The relationship between these various organisational levels is shown in the diagram.
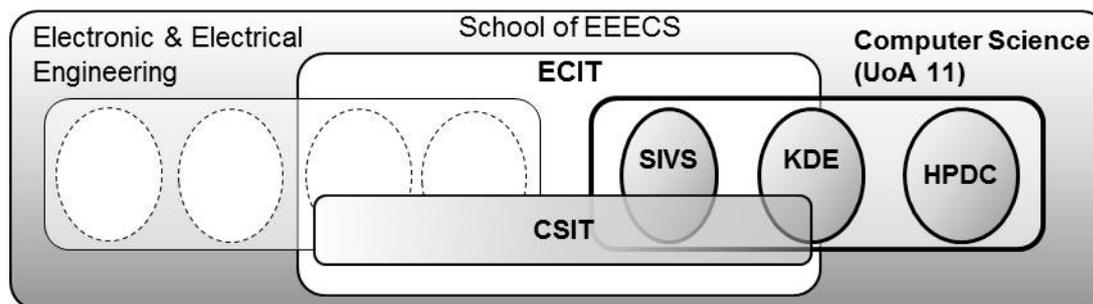
b. Research strategy

Prior to the start of the assessment period, researchers in Computer Science undertook a top-down Foresight-like strategic planning exercise, with full institutional support, with four objectives:

(i)   To identify the future technological mega-problems that must be solved, globally;

(ii)   To select those problems to which QUB Computer Science could realistically make a significant contribution, given its current major areas of activity;

(iii) To formulate a vision for the future of the unit's research areas and their impact; and

(iv) To plan a strategically focused programme of research, and to recruit world class researchers in the specific fields where we had gaps.

One of the future certainties we identified in a rapidly changing world was that, whatever the future applications of technology, the major challenges will involve the processing of vast amounts of data, through applications such as social media, cloud computing and civic video surveillance. Further, since the data in these future applications will often involve a high degree of uncertainty, the processing will have to involve not just storage and number crunching, but logical reasoning under uncertainty, as well as the challenges of high performance and cloud computing. We therefore identified two key enabling research areas (HPDC, KDE), plus one application-oriented research area (SIVS) which requires the two enabling areas, as detailed in RAE 2008 (RA5). This plan was backed up with a major recruitment programme, the University's World Class Researcher initiative, to recruit a new tier of world class research leadership (see later).

Achievement of strategic aims during the assessment period

Our future plans laid out in RAE 2008 (RA5) contained specific objectives for each of the three clusters. But we also identified some ambitious integrated, multi-cluster goals. Below, we highlight these goals from RAE 2008, and point out examples of our success in achieving these, which

demonstrate the effectiveness of our research planning and management process:
- *Large scale multidisciplinary problems of major social and economic importance*

The creation of CSIT within the School of EEECS in 2009 resulted from a focusing of research plans on national priorities in electronic and physical security, informed particularly by our discussions with Government funding bodies and industry. This £30M UK Innovation and Knowledge Centre (IKC) is funded by EPSRC, TSB and InvestNI, with industry and university contributions of £7M and £8.8M respectively. CSIT has since been designated an EPSRC/GCHQ Academic Centre of Excellence. The SIVS and KDE clusters are key funded participants.
- *Audio-Visual Surveillance and Behaviour Monitoring combining SIVS and KDE*

Through the CSIT Grand Challenge 'Secure Transport Corridors' project, a demonstrator system for tracking humans in enterprise environments (e.g. a bank), integrating novel vision algorithms (from SIVS) and an event-driven, multi-agent system (from KDE), has been handed over to our CSIT commercial partners, including BAE Systems, Roke Manor and Thales.
- *Acceleration of video applications combining SIVS and HPDC*

The need for agile algorithmic development led to a switch from FPGAs to GPUs and multicore as a computing platform. Two projects demonstrate our success in using HPC for SIVS applications:
(i) As part of the CSIT Accelerated Video Forensics project, we delivered to Thales and Roke Manor an accelerated background subtraction system which exploits compressed domain, multicore and vector processing, to achieve a speed-up of 170x on a single chip (see Miller #4).
(ii) As part of the £2M LAMDA project in 3D/4D Confocal Microscopy, GPU acceleration of data-intensive image processing operations has led to a new Andor product range.

At research cluster level, the following are key research achievements during the period.

High performance and Distributed Computing (HPDC) (Nikolopoulos [Director of Research], de Supinski, Kilpatrick, Scott, Spence, HA Stewart, Trehan, Vandierendonck)

The HPDC Cluster has made seminal contributions that span the various layers of scalable computing (see the summary of contributions in the figure).
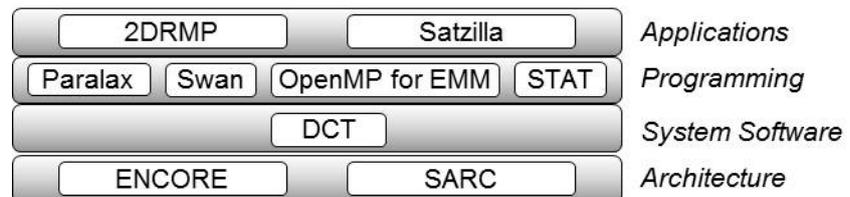
- **Architectures**: Nikolopoulos has been instrumental in the design of the SARC and ENCORE many-core processor prototypes (Nikolopoulos #3). SARC and ENCORE were major EU FP6 and FP7 projects with over €11 million during the REF period. The projects were the first to deliver processor architecture prototypes designed with technology developed exclusively in the European space, after an almost 15-year hiatus in European research in the area of computer architecture.
- **System software**: Nikolopoulos pioneered dynamic concurrency throttling (DCT), a method that reduces system power consumption while sustaining performance in compute-intensive applications (Nikolopoulos #1). DCT underpins an IBM patent for monitoring the power and performance range of applications running on many-core processors and is successfully deployed on IBM BG/L and BG/Q supercomputers at Lawrence Livermore National Laboratory, providing tangible reductions of more than 10% in the computing energy budgets of these supercomputers.
- **Programming languages and tools**: Nikolopoulos and Vandierendonck are world-leading experts in semi-automatic parallelisation with dataflow annotations. Their Paralax and Swan frameworks (Vandierendonck #1 and #3) parallelise large-scale software from simple code annotations without exposing any communication or synchronisation details to the programmer. Their pioneering research in this area has largely influenced the OpenMP parallel programming standard towards adopting dataflow execution semantics. Also, De Supinski has developed STAT, an MPI debugging tool which can effectively track and mine subtle parallel software errors across millions of threads. STAT is the only technology of its kind available worldwide and was the recipient of a **2011 R&D 100 Award** (https://computing.llnl.gov/code/STAT/). Nikolopoulos's research on compiler and runtime support for explicit management of the memory hierarchy (Nikolopoulos #2) has been acknowledged by IBM as the only research that outperformed their commercial compiler products for heterogeneous many-core architectures.
- **Applications**: The HPDC Cluster has released or contributed to widely used open-source libraries and algorithms that exploit the latest HPC architectures, including the Paralax, Swan and

STAT frameworks, 2DRMP (released by Scott #1 and funded by EPSRC Grants EP/F010052/1, EP/C001753/1 and GR/R3118/01), and Satzilla (released by Spence in collaboration with researchers at the University of California, http://www.cs.ubc.ca/labs/beta/Projects/SATzilla/).

Recognitions of excellence include the **Best Technical Paper Award** at the 2012 IEEE/ACM Supercomputing 2012 (de Supinski), the **Best Technical Paper Award** at 1st Workshop on Code Generation and Optimisation for Many-Cores (COSMIC 2013, Nikolopoulos), and a **best paper** selected for journal publication at the 2010 ACM Int. Conf. on Computing Frontiers (Nikolopoulos).

Knowledge and Data Engineering (KDE) (Liu [Director of Research], Bell, Dubois, Godo, Greer, Hong, McCollum, McMullan, Murphy, Sierra, Wilson)

One of the KDE cluster's main goals is to make significant theoretical contributions to fundamental problems in reasoning under uncertainty. Some key achievements in this area include:

- The first fully implemented system based on probabilistic logic programming that measures the relevance between underlying probabilistic knowledge and a user query, with some new theoretical findings [Liu #1].
- The world's first published work using Dempster-Shafer theory of evidence to combine multiple matchers for matching query interfaces to web databases [Hong #1]. It is the first to use a DOM tree representation, semantic similarity and generic grammar rules to extract query interfaces to web databases [Hong #4].
- A major contribution to the unifying of various practical uncertainty representation models in the framework of imprecise probability theory [Dubois #1-4]. Dubois awarded the 2012 **Scientific Excellence Award** from the European Society for Fuzzy Logic and Technology (EUSFLAT).
- In mathematical fuzzy logic, we highlight the development of general algebraic methods for a wide class of system of mathematical fuzzy logic (Godo #2), which has been **the most cited** in the journal (Annals of Pure and Applied Logic) since 2007.
- Pioneering work in the theory and practice of Agreement Technologies and on Electronic Institutions [Sierra #1-4], and has produced algorithms for the interpretation of norms, to empower agents to negotiate and to model trust and reputation in multiagent systems.
- Developed a different semantics and algorithm that allows checking dominance between assignments in low order polynomial time (Wilson), and developed this new dominance for conversational recommender systems. Won a **best paper award** at ICTAI-2010.

The KDE cluster also pursues selected applications of AI. Some notable achievements include:

- In the software process, a novel taxonomy of requirements change has been developed. The work received a **best paper award** at Requirements Engineering 2011 [extended in Greer #1].
- Risk analysis with an imprecise probability approach, separately handling uncertainty due to variability and to partial ignorance. An **award-winning paper** (Risk-informed decision-making in the presence of epistemic uncertainty) in the Int. Journal of General Systems in 2012 arose from a project on the safety criteria for Carbon dioxide underground storage (Dubois).
- Optimisation algorithms developed at Queen's (McCollum #1-4, McMullan #1-4) have been commercialised by a spin out company, EventMAP, and are now used in over twenty institutions worldwide. In one commercial planning project, Victoria University, Australia have estimated that engagement with EventMAP led to construction cost savings of £70m.

Speech, Image and Visions Systems (SIVS) (Crookes [Director of Research], Ji, Kurugollu, Martinez del Rincon, Miller, DW Stewart, Zhou)

Staff in SIVS are located in ECIT, and many of the projects are in response to analysis by ECIT/CSIT stakeholders, including leading commercial companies (e.g. BAE Systems, Thales, Roke Manor) and government organisations (e.g. GCHQ, Home Office). The cluster addresses the extreme challenges and uncertainties posed by real world, unconstrained speech and video data, rather than sanitised data sets. The cluster focuses on Intelligent Video Surveillance, Data Security, Biometrics and Speech enhancement and separation. Some key achievements include:

- A flagship demonstrator system for robust tracking of humans in crowded environments (typical of airports), using novel tracking algorithms and evidential reasoning, has been handed over to BAE Systems, Roke Manor and Thales, and presented recently at AVSS 2013.
- We have delivered to Thales a Video Event Browser, for continuous surveillance on a mobile device (a Google Nexus 7 tablet). Thales present this system at Trade Shows. This integrates

novel research in video event detection and event search and retrieval.
- The paper "Object tracking using SIFT features and mean shift" (Zhou #1) won the 2012 CVIU **Most Cited Paper Award** by Elsevier. The method has been selected for **inclusion in OpenCV**, as part of the tracking framework (http://code.opencv.org/projects/opencv/wiki/2011).
- In the worldwide Break Our Steganography System (BOSS) contest in May 2011, our system initially came second, and shortly afterwards outperformed the winning system. (Kurugollu #1)
- Collaboration with Andor, a world leader in high performance confocal microscopy, has facilitated the launch of Andor's new range of Resolution DSD confocal microscopes. Our GPU implementations have led Andor to establish their own GPU capability within the company.
- A fundamentally new corpus-based approach to Speech Enhancement and Separation outperforms existing state-of-the-art single-channel systems for spontaneous, unconstrained noise (see papers Ji #1,#2,#4). Our Interspeech 2010 paper was selected as the **best paper** in Speech Enhancement. Our work led to collaboration with Cambridge Silicon Radio (CSR), who reported that it "has shaped CSR's R&D research agenda in speech enhancement", "has inspired ideas for new product improvements", and "has helped establish Belfast as an audio research centre of excellence within the company".
- Novel research in audio-visual speech processing has led to a new biometric product based on the uniqueness of lip and facial movements when speaking. A proof-of-concept product (Liopa) won the NISP 25K entrepreneurship award in Digital Media and Software, and already has its first commercial partner. A new spin-out company is being established.

Future strategic aims and goals for research
The research strategy for the three clusters will be driven by a series of major grants and proposals, many of which have already been funded, and some under preparation. We have already established the ability to combine the strengths of multiple clusters as and when required. While the term 'Big Data' has perhaps become all-pervasive, each of the clusters' plans will address different aspects of strategic importance in this area, reflecting each cluster's strengths. Each cluster has also developed an Impact Strategy, which has influenced the plans below.

High Performance and Distributed Computing (HPDC): In 2012/13, the HPDC Cluster has already been awarded £12m of competitive external EPSRC and EU FP7 funding. This defines many of the cluster's goals for the next five years. We have identified the cross-cutting areas of *zero-power computation* and *computing with uncertainty* as areas of thrust that will necessitate disruptive innovation in the future. We will explore how fundamental assumptions about high performance software design need to be revisited in operating systems, programming languages, libraries and applications to cope with and embrace uncertainty in computation. The cluster views uncertainty as a fundamental tool to maximise efficiency and sustainability in computing systems.

This exploration will involve addressing an ambitious research agenda, including the following (for which funding in several cases has already been obtained): energy-efficient micro-server architectures and software for real-time data analytics (via the €3.3m "NanoStreams" FP7 STREP project); computing at the limits of power and reliability (via the €1.8m "SCoRPiO" FET Open project); energy abstractions for parallel programming languages (via the EPSRC ALEA project, ranked first by the panel); energy-proportional heterogeneous computing with morphable processors (via the EPSRC ENPOWER project, also ranked first); high-capacity non- volatile memory technologies for the post-DDR era (via PhD studentships funded by SAP and IBM); and topology-aware cloud computing (via the €3.4m "CACTOS" FP7 STREP project).

Knowledge and Data Engineering (KDE)
Challenges arising from (big) data-driven and (distributed) knowledge-driven large-scale intelligent systems for real-world applications have set new research agendas for the Artificial Intelligence and Database communities. Two new major real world inter-disciplinary projects will drive impact of, and provide the context for, a number of our more theoretical and fundamental research themes: (i) The recently-announced £6m LNiK-ESRC Northern Ireland Administrative Data Research Centre (Hong is one of five project leaders); and (ii) the next phase of CSIT funding, currently under preparation in collaboration with SIVS and CSIT. The demands for analysing and reasoning about vast data repositories will be met by addressing the following objectives:
- Advanced knowledge and information fusion algorithms for combining information from multiple

- sources under uncertainty, incompleteness, and inconsistency.
- Novel belief revision and dynamic planning approaches to responding to uncertain environment changes for multi-agent based autonomous and adaptive intelligent systems.
- Scalable and privacy-preserving machine learning techniques for analysing large-scale datasets, for extracting and integrating data from deep Web, social media, and other forms of sensory data.

Our ongoing research programmes in new techniques for enhancing software adaptability and security, and for scheduling and optimization of complex systems, will continue to be pursued.

Speech, Image and Visions Systems (SIVS)

The success to date of the SIVS components of CSIT has laid the foundation for the next generation of very large scale security-related systems. Our goal is to process multiple streams of complex, noisy, real-world data intelligently and in (near) real time. The challenges of processing this quantity of data, and the inevitable uncertainty associated with interpreting real world video and audio data, will drive the SIVS agenda for the next five years, in collaboration with the KDE and HPDC clusters. Achieving this goal gives rise to the following strategic objectives:

- Moving further from processing data to processing events (in video and audio). This will require new robust event recognition techniques and advances in machine learning. Another promising approach will be to apply our speech corpus-based approach to video data.
- With KDE, we will pursue the concept of cyber-physical security – the convergence of both the cyber and physical security domains. This is important for the insider threat problem, to protect critical national infrastructure such as airports, power stations and even intelligence agencies.
- Reasoning under uncertainty at the data level, for sensor fusion (with KDE).
- Acceleration of multi-stream processing using new architectures such as the Intel Xeon Phi.
- Multi-modality person recognition and tracking, exploiting modalities including gender, age, lip and facial movements, gait and 3D range imagery using a time-of-flight camera. New approaches such as Deep Neural Networks will also be investigated for these problems.

These objectives underpin the application for the next phase of CSIT funding, under preparation.

c. People, including:
i. Staffing strategy and staff development

The QUB Computer Science strategic research plan for the period was backed by a major University-led 'World Class Researchers' programme of investment and disinvestment, with the goal of attracting internationally leading professors and high quality academics. In Computer Science during the REF 2014 period, this has resulted in the appointment of: two full time professors as Directors of Research (**Nikolopoulos** and **Liu**, an internal appointment); five Early Career Researchers (**Martinez del Rincon**, **Murphy**, **Trehan**, **Vandierendonck**, **Zhou**); and, in an ambitious strategy to increase international collaboration with world leading researchers, five new professors have been appointed at 0.2 (Professors **Dubois**, **de Supinski**, **Godo**, **Sierra**, **Wilson**). Since 2008, 7 academics have retired (Prof Bell was retained at 0.2) or have moved, typically to more senior academic positions elsewhere, and their replacement with younger staff and internationally leading researchers has enhanced the vibrancy and age profile of the unit.

The success of this initiative has entailed a careful programme of staff integration. Cluster-based Away Days have been used to ensure all researchers, including new staff, have full ownership of the strategic planning process. To integrate the 0.2 professors, a programme of in-cluster and cross-cluster research sessions and workshops was implemented. This has resulted already in joint publications and joint research grants.

Staff development

All new staff undergo a probation period of typically three years, and have a mentor to provide guidance and advice. Each new staff member is provided with a cash start-up package of £12k to fund travel and infrastructure. For all staff, there is also an active appraisal scheme. This is a supportive process in which staff reflect on their progress over the year and how it relates to their objectives and those of the cluster, School and University. This is tied in to the School's formal strategic planning process which operates on a 3 year cycle, with plans and objectives set annually at School and Research Cluster level, in light of University objectives. This process is both bottom-up and top-down, to ensure on the one hand that staff have input to the direction and plans, but also maintaining focus and impact potential. The process is supplemented by a generous training

and development plan, for which the School receives addition central funding (approx. £125k per year). The School of EEECS was one of the pioneers of a new 'Peer Mentoring for Early Stage Researchers' scheme for all new research staff. Also, to develop potential future leaders and ensure succession planning, several senior staff in the UoA have participated in a special centrally-funded Leadership Development programme.

The University has been awarded the **European Commission's HR Excellence in Research Award** for its efforts in improving the working conditions and career development opportunities of its researchers. This links to the **Concordat for the Career Development of Researchers** covering key principles relating to topics such as recruitment, retention, diversity and equality. The School of EEECS is committed to developing the potential of all its staff, by investing in its people and in ensuring **equality and diversity** are promoted. All established staff must take a compulsory course in Equality and Diversity.

External recognition of excellence and leadership in these areas of staff development include:

• **Investors in People Award**. Investors in People specialises in transforming business performance through people. ECIT was the first department within Queen's to receive the nationally recognised award in 2012, and the School of EEECS received the award in 2013 – the first school in Queen's to achieve this award. The assessor highlighted: *the recently developed Staff Charter was identified as excellent – a sound framework for the delivery of good management practice, and as good as any the consultant has seen; the School's long-standing commitment to continuous professional development is recognised; the peer mentor scheme is one of several examples of how EEECS works collaboratively and in partnership with others to achieve results; and by taking a systematic approach to performance improvement, and by effectively managing under-performance, EEECS is now competing with the very best*.

• **SWAN Silver Award**. In 2012, the School of EEECS received the Athena Swan Silver Award in recognition of its good practice on recruiting, retaining and promoting women. Queen's was also the first ever UK University to be awarded a Silver institutional honour at the Athena SWAN Charter awards in 2012. Queen's is the UK university with the most departmental silver awards.

As of October 2013, the international make up of staff within the UoA is diverse but balanced: 12 UK, 7 EU and 7 other.

Staff consultancy: The UoA uses consultancy as a rapid and agile means of technology transfer and innovation, and for enhancing our impact on society and the economy. Cloud Computing, Content-based Image Retrieval, and Data Mining are areas where staff have helped several innovative companies gain a competitive edge in a rapidly evolving international market.

ii. Research students
Research Student Recruitment Strategy
One of the UoA's novel approaches to PhD recruitment has been to build strategic relationships with relevant research-hungry companies or consortia of companies, and to create sustainable programmes of PhD research programmes with additional support from the University and from InvestNI. Successful funded PhD programmes include: the SAP programme in Cloud Computing, and a consortium of six leading Capital Markets companies including Citi Group and New York Stock Exchange Technologies, for research into acceleration technologies and AI-based prediction and anomaly detection in stock markets. The UoA employs a PGR recruitment officer, and a number of staff act as international champions. Targeted links with China and India have resulted in funded initiatives to support international research student recruitment, e.g. with Harbin IT, a top 10 Chinese university. (We note in passing that the UoA's statistics on completing PhD students for the REF period suffer from a particular anomaly in the time bounds, in that eight students who completed in January-July 2008, and five likely to complete in September-December 2013, are not able to be reported in this, or any, REF.)

The central University Postgraduate Office provides support in terms of research opportunities and studentships. Widely advertised postgraduate open information sessions are held each year. Research opportunities and PhD studentships are advertised on School and University dedicated web sites and in the press. UG and PGT students are actively encouraged to consider research opportunities. The University is required to monitor Tier 4 international students, and all research students are required to maintain regular contact with their supervisors.

Over the REF period approximately two thirds of graduating PhDs went into industry, and one third into university research posts.

Research student environment

In 2011 Queen's opened a £1.3m International and Postgraduate Support Centre which provides dedicated support and facilities to all the University's postgraduate students. Also in 2011, a new £50m library was opened. Our Postgraduate Researcher Development Programme (PRDP), which links directly with the (vitae-developed) **National Researcher Development Framework**, supports PGR students in the development of their research and transferrable skills, career development and employability. The IPSC Centre has a dedicated PG training team as well as state-of-the-art facilities within the PG student centre. An online 'Personal Development Planner' tool has been developed to facilitate training and development needs analysis. A Researcher Plus award, an initiative welcomed by business, provides accreditation for the development of transferrable skills.

In 2011 the School of EEECS launched its own **Research Society** whose mission is to enhance the experience of research students and post-doctoral workers, by providing a voice for the research community and to promote opportunities for career advancement, personal development and social interaction. Research students are invited to attend internal development sessions (for instance the IET run an annual in-house course on 'Technical Paper Writing').

The School has pioneered a Postgraduate Peer Mentoring scheme, where all new 1st year PGR students have a mentor to support them with the transition to the research environment.

The latest national 2013 PRES survey reflected the effectiveness of the research environment in the School of EEECS: with a 58% response rate (sector average 42%), the scores for Overall Satisfaction were: QUB EEECS **84.6**%, UK HEI Sector **81.6**%, and Russell Group **82.4**%.

d. Income, infrastructure and facilities

Since January 2008 the UoA research funding portfolio consists of a balance of mainly EPSRC, TSB, Industrial and InvestNI funding. Some notable grants awarded or active during the period are: ISIS (EPSRC, £1.4m), CSIT Grand Challenges (EPSRC, £2.1m) and the Andor LAMDA grant (InvestNI, £1m to QUB). The UoA is PI or Co-I in several large recent grants totalling some £18m (to all partners), which will ensure a very high level of funded activity in the next period. Major new grant applications to take CSIT forward into a new phase are due for submission early 2014.

Provision, operation, and investment in specialist infrastructure and facilities: Specialised infrastructure and facilities for UoA use were obtained following an award (£330k) from the University's 2010 CRIF scheme. Located at ECIT, these comprise 24 highend servers for single- and parallel- mode processing including HBA connectivity to 4x Fermi class GPGPU (Tesla C2070s), 38TB of scalable backup and archiving storage to provide research continuance and assurance. The UoA is an extensive user of American Leadership-Class HPC Facilities, in particular an IBM Blue Gene/Q (up to 1 million cores) and Cray Blue Waters Systems (up to 352,000 cores) at the NCSA in Illinois, USA. The UoA also uses the University's central HPC facilities, including a 900+ core Dell cluster and a 128 core Windows Compute Cluster.

QUB is investing heavily in Computer Science to expand and enhance research infrastructure, with extensive remodelling of accommodation for Computer Science in 2014 (estimated expenditure of £4m-£6m) and six new academic posts targeted on future research plans, in 2014.

e. Collaboration or contribution to the discipline or research base

Collaborations

As highlighted in the above sections, we have focused on significant collaborations with, and contributions to, key global industrial partners, including IBM, SAP, BAE Systems, Roke Manor, Thales, CSR, and Citi. We increasingly are active players in a range of important EU consortia (e.g. NanoStreams, CACTOS, SCoRPiO, ASAP, GEMSCLAIM, NovoSoft), and EU and UK networks of excellence (HiPEAC, NA-HPC). This global activity is supplemented with collaboration with more local leading industrial players to enhance economic development (e.g. Andor, NYSE).

Conference Chairs or top Organisational Roles (20 examples included)

De Supinski is Technical Program Co-Chair and **Nikolopoulos** is Technical Program Vice-Chair of **Supercomputing'2014**. Program Co-Chair of 14th IEEE/ACM Int. Symposium on Cluster Computing and the Grid (CCGrid'14) (**Nikolopoulos**). Program Chair of 25th ACM Int. Conf. on Supercomputing (ICS 2011) (**De Supinski**). 18th IEEE/ACM Int. Conf. on Parallel Architectures and Compilation Techniques (PACT 2009) **(de Supinski)**. **Nikolopoulos**: Program Chair of IEEE/ACM ScalCom'11, General Chair of IEEE/ACM 2010 Int. Conf. on Cluster Computing. General Chair of 20th European Conf. on AI (ECAI 2012) (**Dubois**). Program co-chair of Int. Conf. on Scalable Uncertainty Management (SUM2009) (**Godo**). PC Co-Chair of SUM2013 (**Liu**). General Chair of AAMAS 2009 (**Sierra**). Local Chair of IJCAI 2011 (**Sierra**). Conference and Program Chair of

ECSQARU'11 (**Liu**). PC Co-Chair of 10th Int. Conf. on Fuzzy Systems and Knowledge Discovery (FSKD 2013) (**Hong**). Conference Chair and Organizer of 8th Int. Conf. on the Practice and Theory of Automated timetabling (PATAT10) (**McCollum**). Chair and Organizer of Int. Workshop as part of ICCV 2011 (**Martinez**). Chair and Organizer of IEEE Int. Workshop as part of CVPR 2013 (**Martinez**). Chair of VISAPP 2011 (**Martinez**). Chair and Organizer of SPUnd workshop (part of WI-IAT 2013) (**Martinez**). Chair of ACM Workshop as part of ACM Multimedia 2011 (**Zhou**).

UoA members have served on over 150 conference program committees during the period.

Invited Keynote Lectures (20 examples included)

Nikolopoulos: EnaHPC'13 (Dresden), Euromicro PDP'13 (Belfast), MultiProg'10 (Heraklion). **De Supinski** served in the ACM Distinguished Speakers Program in 2010. 2012 SIAM Conference on Parallel Processing for Scientific Computing (**Nikolopoulos, de Supinski**). Intelligent Computing for Sustainable Energy and Environment (ICSEE2012) (**Scott**). Int. Conf. on Mathematical Modeling and Computational Physics (MMCP 2009) (**Scott**, **Spence**). Int. Conf. on Agents and Artificial Intelligence (ICAART 2011) (**Dubois**). 12th Int. Conf. on Artificial Intelligence and Law (2009) (**Sierra**). 10th Mexican Int. Conf. on Artificial Intelligence (2011) (**Liu**). ERCIM Workshop on Constraint Solving and Constraint Logic Programming, Rome (2008) (**Wilson**). Modelling Decisions in Artificial Intelligence (MDAI'09) (**Godo**). 8th Int. Conf. on Advanced Data Mining and Applications (ADMA12) (**Bell**). Probability, Uncertainty and Rationality (2009) (**Godo**). Advanced Video and Signal-Based Surveillance (AVSS 2010) (**Crookes**). PATAT 2012 (**McMullan**). China-UK Bilateral Symposium on Life System Modeling & Simulation (**Zhou**). Workshop on Security Solutions in Information Hiding and Face Recognition, India, 2013 (**Kurugollu**).

Nikolopoulos, **Vandierendonck** and **Kilpatrick** have also given invited talks in 15 Computing Systems Weeks organised by the EU Network of Excellence in HiPEAC.

Awards, Prizes and Fellowships: In addition to the awards mentioned above (**de Supinski**, **Zhou**, **Dubois**): Marie Curie International Reintegration (IRG) Fellowship (2009) (**Nikolopoulos**). Fellowship, European Network of Excellence (HIPEAC 2008) (**Nikolopoulos**). Marie Curie Intra-European (IEF) Fellowship (2012) (**Vandierendonck**). In addition to the Best Paper awards above: IMVIP 2009 (**Crookes**), BMVC 2011 Best Poster Award (**Martinez**). **Scott**, **Crookes** and **Bell** are Fellows of the BCS. Senior member of IEEE (**Crookes**, **Kurugollu**, **Vandierendonck, Scott, Nikolopoulos**), and of ACM (**Nikolopoulos**). IET Fellow (**Scott**). Adjunct Professor, Shanghai University, China (**Scott**). Winner of NISP 25K Entrepreneurship Award 2013 (**DW Stewart**).

Membership of External Bodies: **Nikolopoulos** is a member of the Canadian NSERC Computer Science Discovery Grant Panel, and a panellist for the US National Science Foundation, the US-Israel Binational Science Foundation and the EU FP7. **De Supinski** was a panellist for the US National Science Foundation and the US Department of Energy. **De Supinski** chairs the OpenMP language committee. **De Supinski** is CTO of Livermore Computing, responsible for the procurement and deployment of some of the most powerful supercomputers in the world, including the top-ranking Sequoia Blue Gene/Q, the first supercomputer to exceed 1 million cores. Scott is a member of the Scientific Committee, EPSRC Network NA-HPC (**Scott**). **Zhou** is member of the IEEE Computational Intelligence Society (ISATC) Robotics Task Force. **Scott** is a member of the REF 2014 UoA 11 panel. Members of EPSRC College include **Crookes**, **Ji**, **Liu**, **McCollum**.

Journal Editorial Boards

Editor in chief: Elsevier's Computer Physics Communications (**Scott**). CPC International) Program Library (**Scott**, Library Director). Fuzzy Sets and Systems (**Dubois**, Co-Editor-in-Chief). Associate Editor: Soft Computing (Springer) (**Godo**). **Zhou**: Int. Journal of Image & Graphics, American Journal of Science and Engineering, Int.Journal of Image Processing.

Editorial boards/Guest Editor (20 examples) IEEE Transactions on Parallel &Distributed Systems (**de Supinski**). Int. Journal of High Performance Computing Applications (**Nikolopoulos**, **de Supinski**). Elsevier's Sustainable Computing: Informatics & Systems (**Nikolopoulos**). Int. Journal of Parallel, Emergent & Distributed Systems (**Nikolopoulos**). Artificial Intelligence Journal (**Sierra**). Journal of Artificial Intelligence Research (**Sierra**). Int. Journal of Database Theory & Application (**Hong**). Information Systems (**Bell**). Software Practice & Experience (**Greer**). Int. Journal of Computer Vision & Signal Processing (**Martinez**). Int. Journal of Distributed Sensor Networks (**Martinez**). Advances in Artificial Intelligence (**Liu**). **Zhou**: Pattern Recognition, Neurocomputing, Int. Journal of Biometrics, Int. Journal of Imaging & Robotics, Signal Processing. Int. Journal of Digital Crime & Forensics (**Kurugollu**). American Journal of Signal Processing (**Ji**).