Institution: University of Stirling

Unit of Assessment: B11 Computer Science and Informatics

a. Overview

Research in Computer Science and Informatics at Stirling is inherently inter-disciplinary and has expanded significantly since RAE 2008. It is based in the Division of Computing Science and Mathematics within the School of Natural Sciences and it represents ground breaking innovations which lie at the interface of Computer Science, Operational Research, Management Science, Biology, Aquaculture, Environmental Science and Social Science. Moreover, our research has a strong focus on stakeholder engagement and it addresses key industrial and societal challenges in partnership with a wide network of collaborators from across industry, commerce and the public sector. Our research is centred around three complementary research groups which have the common theme of investigating complex systems in uncertain and dynamic real world environments. Our three groups are, *Computational Heuristics Operational Research and Decision-support Systems* (CHORDS: Burke, Benlic, Epitropakis, Li, Ochoa, Woodward), *Modelling and Analysis of Complex Systems* (MACS: Bracciali, Farkas, Hoyle, Kleczkowski, Norman, Shankland, Turner) and *Cognitive Computation* (CC: Graham, Hussain, Smith). The number of our submitted staff has increased by 44% from RAE 2008. A major change occurred in late 2011 with the appointment of Prof Burke as Deputy Principal for Research from the University of Nottingham and with the establishment of the CHORDS group. Our work has been underpinned by major EPSRC, BBSRC and ESRC awards in collaboration with other universities across the UK including an EPSRC Programme Grant, an EPSRC Platform Grant, a £1.2M EPSRC award on healthcare modelling and a £900K ESRC grant.

b. Research strategy

Our research vision is ***to investigate novel and effective approaches to dynamic and uncertain real world problems in complex systems and environments by exploring inter-disciplinary synergies between Computer Science, Mathematics, Life Sciences, Social Sciences and Management. This requires focussed collaboration with leading academics in other disciplines and other universities. Close engagement with key stakeholders in industry and the public sector also plays a critical role in our research strategy***. ***We aim to push the boundaries of the levels of complexity that we are able to model and handle.***

This fits with the University's stated research strategy, engaging with communities outside the University and it fits with the School of Natural Science's research strategy of developing rigorous empirical and multi-disciplinary frameworks given predictive power through computational, mathematical, quantitative modelling and informatics technologies. Within the overall strategic vision of the Unit of Assessment (UoA), the three inter-related groups reflect different approaches and different scientific challenges, all of which have the common theme of addressing complex scientific issues across a broad range of real world environments.

The **CHORDS** group is led by Prof Burke and carries out leading edge inter-disciplinary research into the investigation of computational search methodologies and models that emerge from studying the complexity and uncertainty of real world scheduling, optimisation and decision support problems. Its transformative research agenda has two key strategic goals. Firstly, the group investigates innovative exact, heuristic, metaheuristic and hybrid computational search methods with the goal of closing the gap between industrial practice and academic decision support research. It aims to explore a broad range of real world problems across industry, commerce and the public sector. There is a particular focus on research challenges in timetabling, manufacturing, personnel scheduling and air transport scheduling. In addition, we have the objective of developing a deeper theoretical understanding of complex real world problem solving scenarios in order to inform more effective practical decision support system development. Secondly, the group is exploring how to automate the heuristic design process by investigating computational methods that can automatically build decision support systems, especially within the context of search based software engineering problems. Pioneering work is being addressed in Hyper-heuristics, which can be thought of as heuristics to choose or generate heuristics. Members of the CHORDS group (particularly Burke, Li, Ochoa and Woodward) have played an important role in setting the international agenda in this field, in which the UK has led the way. This is

evidenced by the following comment from the EPSRC International Review of Mathematical Sciences' report, January 28th 2011 (pages 18-19): "*Especially notable research includes creation of novel heuristic approaches in search and optimisation. In particular, UK work on hyper-heuristic methods is world-leading and has had a significant international impact; these methods address important mathematical problems from applications that cannot be solved today by conventional exact techniques, and are closely connected with computer science*".

The **MACS** group is led by Prof Norman. Its core focus is to develop innovative inter-disciplinary computational and mathematical modelling approaches to high impact real world problems and to deepen our understanding of the environment in which we live. One of its key goals is to model disease spread in different environmental systems and to enable a single problem to be modelled in complementary ways. MACS has strong interdisciplinary collaborations with the Life Sciences. The University has recently invested heavily in aquatic food security (one chair, one senior lecturer and three lecturers). This represents a strategic multi-disciplinary investment in Computer Science, Mathematics and Aquaculture. A growing global population, climate change, disease, dwindling supplies of sea fish stocks and an increase in wealth in developing countries all mean that the demand for aquatic food is expected to increase significantly over the next 40 years. The aquatic food security initiative is being driven by Prof Norman and will explore how inter-disciplinary synergies between computational modelling and aquaculture can address key issues facing the seafood industry. Stirling is playing a leading role in the Scottish Government's new £11M Innovation Centre in Aquaculture and MACS will have a key part to play in the activities of the Centre. Another important strategic aim of the MACS group is to address modelling issues in home and healthcare technologies. The group has the goal of improving disease treatment through effective predictive modelling and close inter-disciplinary collaborations with the Social Sciences and Management Science.

The **CC** group is led by Prof Smith. It is distinct from CHORDS and MACS in concentrating on deriving computational techniques (such as pattern recognition and the control of autonomous systems) from studying animal nervous systems, in addition to investigating models to deepen our understanding of neuroscience and biological nervous systems. One of the Group's main strategic drivers is the exploration of personal opinion and sentiment mining of natural language. This has led to the development of a suite of computational technologies under the name of Sentic Computing that is having major impact in areas ranging from analysing clinical patient personal statements to personal online photo management systems (see case study and section 3a).

The primary changes from the RAE 2008 strategy are that we are submitting a clearly integrated set of research groups all built around addressing our strategic goals within the context of their common theme of addressing complex, uncertain and dynamic real world problems. These groups are all strongly focussed on both external and internal collaboration across the University, with other universities and with external organisations/companies. The 2014 Unit of assessment represents 14.4 staff whereas the 2008 submission represented 10 staff. This reflects a 44% increase in our submitted staff. The CHORDS group is entirely new and represents a major investment on the part of the University. The MACS group has arisen from the Applied Formal Methods and the Communications and Services groups (submitted in 2008) but has changed significantly to reflect a focus on our strategic goals. The Cognitive Computation group was called Computational Intelligence in RAE 2008, is now more focussed and has strengthened cross-collaboration with CHORDS and MACS. The arrival of the CHORDS group in 2012 has significantly strengthened the MACS and CC groups, as the approaches investigated by CHORDS are of direct relevance to the problems being tackled by them. These changes reflect a tighter focus within the UoA. They also reflect the influence of being a part of the Scottish Informatics and Computer Science Alliance (SICSA). In addition, we currently have major new RCUK awards and significant University investment to underpin our strategic goals and to support our research vision.

c. People:

Staffing strategy and staff development

The period 2008-2013 has been one of major investment in this UoA by the University to support our research vision. Stirling's commitment to the SICSA initiative guaranteed the appointment of Bracciali, 50% funded by SICSA and Stirling. He has played a major role in the formation of the MACS group. The arrival of Burke from the University of Nottingham led to the establishment of

CHORDS, which has recently appointed Benlic, Epitropakis, Ochoa, Li and Woodward. The Division is strongly committed to providing a supportive environment in which early career staff can flourish. For example, Benlic and Epitropakis have 0.2 lecturing and 0.8 research positions to enable them to gain some academic experience beyond that normally expected of a post-doctoral research only post. In addition, the University has invested in two early Career Transitional Fellowship positions for this UoA. These posts underpin our commitment to early career support and sustainability. They provide funding for a period (1 to 3 years) of sustained independent research activity followed by a 'transition' to a full time permanent lectureship. Ochoa held one of these fellowships and transitioned into her lectureship post in June 2013. We have an additional Transitional Fellow (Swan) who will take up a lectureship in September 2015.

We have made a number of important international appointments since 2008: Bracciali (from Italy), Benlic (from France), Epitropakis (from Greece), Li (from China) and Woodward (from China). The last two members of staff moved from the University of Nottingham's Ningbo Campus in China. In addition, we have had visiting scholars join the CHORDS group to contribute to our world leading research agenda. Prof Hugo Terashima from Tecnologico de Monterrey, Mexico is spending a sabbatical with us (Aug 2013 – June 2014) to work on hyper-heuristics. One of his PhD students (Alejandro Ascencio) has also spent a period of study (March – Dec 2013) in Stirling to work on the same topic. Associate Professor Mauricio de Souza from the Federal University of Minas Gerais, Brazil is spending a sabbatical with CHORDS (April 2013- Feb 2014) to work on surgery scheduling. He also had an accompanying PhD student (Thiago Silva) who was with us from Aug 2013 to Nov 2013.

We take great care to support new staff and to integrate them rapidly into our research culture so that they quickly become established and productive researchers. Early career researchers are allocated a senior colleague mentor who is able to provide day to day advice on research matters and achieving their goals. New lecturing staff are subject to a University probationary period, normally of 2 years, which requires them to produce a research plan and sets goals in respect of publications and research grant applications. In order to monitor and enhance the potential of individual researchers, a performance review scheme "Achieving Success" is undertaken by all staff on an annual basis. This is recognised by colleagues as an important aspect of personal development. Staff reflect on their achievements in the last year and plan short and long-term goals for the future. The review scheme is also used as a means of providing information on staff activities, aspirations and resource requirements and allows the development of the School's planning and promotions process. Non-probationary academic staff are eligible for one six-month period of research leave after six full semesters of completed service. A case for research leave is made to the Head of School, approved by Staffing Committee and reported within one semester of return to normal duties. Appropriate activities include the development of new research proposals, extended collaborative research visits and research paper writing. Nine staff from this submission have taken six month periods of research leave during the census period.

The University has strategic commitments to valuing and promoting equality and diversity in research careers and this work is championed by an established network of equality contacts. Flexible working is available to those with caring responsibilities, there are clear policies on consideration of career breaks and part time working in terms of advancement and promotion and there are strengthened guidelines for appointing committees to address equality issues. Within the School of Natural Sciences, there are locally agreed, flexible working arrangements. The School has led University Athena SWAN initiatives; the Athena SWAN national charter for women in science was signed in 2011 and the bronze level institutional award gained in 2013. Indeed, a member of this UoA (Shankland) led the University's successful bronze level Athena Swann application. We are now actively pursuing the Athena SWAN silver award.

The University was one of the first signatories in the UK of the RCUK Researchers Concordat in 2009, with its implementation earning Stirling the EU HR Excellence in Research Award in 2011. Further evidence of the Concordat's positive influence is represented by the dedicated funds available for Research Fellows and Research Assistants to attend specialist training events and conferences. Limited bridging funding from one grant to another is also available. Following appropriate training, post-doctoral researchers are given opportunities to

supervise research students as second supervisor and to contribute to research-based teaching. Fellows are mentored by a senior colleague and Research Assistants by project Principal Investigators. The University implements a Code of Good Research Practice that all staff and post graduate researchers are expected to follow. This sets out standards and responsibilities for people involved in research – from project initiation through to publication. It serves to encourage and maintain a culture of respect for the highest standards of integrity and honesty.

Research students

We have doubled the number of our PhD students in the assessment period. In 2008, we had 10 full time and 2 part time PhDs (11 FTE) and we now have 19 full time and 6 part time students (22 FTE). Our role in SICSA has enabled us to appoint four research students during the period by providing 50% funding from the SICSA Prize studentships. The University has also invested in four studentships in our research groups which include industrial matched funding, support that enhances our employability and impact portfolios. Additionally, the University provided ten fully funded PhD studentships as part of the support package for our £6.8M EPSRC Programme Grant with UCL, Birmingham and York. We have two EPSRC Industrial CASE Studentships (with Sitekit Ltd). Co-funding by DEFRA, NERC, industry and research institutes (Centre for Environment, Fisheries and Aquaculture and the James Hutton Institute) have enabled us to recruit a further nine PhD students. We fully recognise the challenges of employability and skills training in our PhD programmes and as an example of our commitment to this agenda the School of Natural Sciences introduced in 2010 a new and innovative Research Apprenticeship Scheme. This offers exceptional candidates a 5 year stipend, during which period they are expected to complete a PhD, gain experience in teaching, and conduct apprenticeship training in advanced research skills. Four such apprentices (across the School) are in place, and we are planning the expansion of this scheme.

PhD students receive a mix of training in a stimulating research environment proven to be successful in delivering timely high quality theses. Training and networking is via the principal and second supervisor (who undergo supervisory training) complemented by the generic research-training programme of the Stirling Graduate Research School and cross-institutional collaborations. All PhD students within the CHORDS group are expected to attend the PhD training courses provided by the EPSRC National Taught Course Centre in Operational Research. Rigorous progress monitoring is via interviews and regular reports to the School's Research sub-Committee and then to the University's Admissions Progress and Awards Committee. PhD students are active attendees in the Division's research seminar programme, and they participate in the annual PhD student conference. All students will normally be expected to have spoken at a national level conference by their second year and at an international conference by their third year. PhD students are expected to submit their first manuscript for publication before the end of their second year, so that by the time of submission they have already published one or more papers in international journals or appropriate international refereed conferences. All recently graduated PhD students are in relevant employment. For example, they represent Research Fellows in different universities (McCaig at Strathclyde, Lintott at Stirling), Developers (Maternaghan at Google, Furness at Microsoft) and lecturers (Hunter at the University of Highlands and Islands).

d. Income, infrastructure and facilities

Income

We have an integrated strategy for generating grant income co-ordinated by the School Research Committee; there is explicit expectation that all colleagues will hold a research grant. We focus on RCUK, EU, industry, selected government agencies and selected international organisations. We actively participate in RCUK agenda-setting meetings and in formal responses to consultation processes. From these intelligence gathering activities, we explicitly match our research groups against emerging funding themes through our strategic planning process. Our Research and Enterprise Office develop and deliver information meetings (our most recent was Horizon 2020) that highlight opportunities and procedures. Grant writing (team and individual) is supported by time made available through workload management and by critical reading of drafts. The review of both successful and unsuccessful applications is disseminated by the School Research Committee.

The transformative research agenda of the **CHORDS** group is underpinned by a joint EPSRC Platform Grant (EP/H000968/1) with the University of Nottingham, worth £1,010,976 (£400K to Stirling). A particular focus of the CHORDS group's work in air transport has been on airport operations and an EPSRC grant of £659,805 (EP/H004424/1 and EP/H004424/2) was awarded to support this in collaboration with Loughborough, Sheffield, Lincoln, Nottingham, Manchester Airport and Zurich Airport. The CHORDS group also plays a role in the EPSRC Science and Innovation LANCS Initiative in Foundational Operational Research (EP/F033613/1). Indeed, Burke was Chair of the Management Board of this initiative and is currently a member of the Executive Committee. The CHORDS group is collaborating very closely with the LANCS consortium, particularly with researchers at Lancaster and Nottingham. CHORDS were recently awarded £2.4M as part of a £6.8M EPSRC Programme grant (EP/J017515/1 - joint with UCL, York and Birmingham). This programme, entitled *Dynamic Adaptive Automated Software Engineering* has the goal of integrating world-leading expertise from Operational Research and Software Engineering to "create a new approach to software engineering, placing adaptive automation at the heart of the development process and the products it creates". This Programme Grant collaborates with ABB Group, Berner and Mattner, BT Laboratories, Ericsson, GCHQ, Honda, IBM, Microsoft Research, Motorola and Northrop Grumman Air Park Systems. In addition, Air France/KLM have recently joined the project team. One of our post-doctoral researchers (Banerjea-Brodeur) is currently on secondment to Westminster and Chelsea hospital, in the surgery department, to support her work on surgery scheduling. The University of Stirling provided ten PhD studentships as part of the support package for the Programme Grant. The CHORDS group has also played a key leadership role in the EPSRC National Taught Course Centre in Operational Research for PhD training (EP/J500938/1).

The **MACS** group has a recent EPSRC award (EP/K039342/1) of £1,228,231, being led by Shankland, to combine mathematical and computational models within a unified framework to explore the synergistic effects of combined treatments for cancer therapies and predictive models for healthcare. This major award represents a collaboration between Stirling, Imperial, Queen's University of Belfast, Nottingham and Cranfield. In addition, Shankland is co-leading the POEMS network (Sheffield, Manchester and Stirling). This EPSRC-funded network grant (EP/L001101/1), worth £254,355, aims to bring together healthcare practitioners and mathematical and computational modellers to develop new technologies that will enable healthcare to be delivered in a more effective and personalised way, through multidisciplinary collaborations. An earlier EPSRC award (EP/E006280/1; Oct 2007 to Sept 2010) of £343,495 to Shankland and Norman established their fundamental work in using process algebra as a modelling tool in epidemiology. Turner led the MACS group's engagement with the ESRC funded DAMES project (RES-149-25-1066, led by Stirling, collaborative with Glasgow) This project was worth £901,714 with Stirling's share being £637,134. It has created a substantial infrastructure for social science research and it represented a major inter-disciplinary collaboration with colleagues in Applied Social Science, Management and the National e-science Centre at Glasgow. Kleczkowski led the MACS group's engagement in the €300,000 ECO-DELIVERY (Designing Markets for Ecosystem Services Delivery) project which was funded by the European Investment Bank and which represented a key collaboration with the Management School at Stirling. The MACS group has also received major University investment (a new Chair) as part of the University's strategic commitment to aquatic food security. In the area of modelling for aquatic systems and antibiotic resistance, collaboration with Cefas is funded by six PhD studentships (since 2008) and a fully funded post-doctoral position. Similarly, collaboration with the James Hutton Institute allowed us to recruit research students to modeling issues on economically important tick-borne diseases.

The **CC** group's strategic goals in the control of autonomous systems have been supported by three significant EPSRC awards. A major project (EP/I009310/1) is exploring Cognitive Computation techniques to control engineering to produce modular systems. This project is worth £352,599 and is led by Prof Hussain in collaboration with Sheffield, Industrial Systems & Control Ltd and SciSys Ltd. Another major project (EP/G062609/1), worth £353,817 and led by Prof Smith in collaboration with Quinetiq Ltd is exploring novel adaptive microphone technology. The third project (EP/D04281X/1; £246,698), led by Graham in collaboration with Glasgow, studied the dynamics of information processing in neural microcircuits. It finished in 2009. Graham, in collaboration with Leicester and Edinburgh, has a new BBSRC grant (BB/K01854X/1) worth

£251,000 to employ computational models to further aid understanding of fundamental aspects of brain operation, particularly in the brain stem auditory system. Smith is an executive member of the EPSRC, and later BBSRC-funded CARMEN project (11 UK universities, led by Newcastle) to provide neuroscience researchers with tools for data sharing and analysis. The CC group's Sentic Computing programme, led by Hussain, has been developed through EPSRC Case studentships and has attracted academic collaboration with MIT and commercial collaborations with a wide range of companies including HP Labs, Microsoft Research Asia, Zoral Labs, Patient Opinion Ltd, Abies Ltd and Sitekit Solutions Ltd. This has underpinned our strategy to realise impact (see impact case study). Hussain also led the European Science Foundation funded Research Network (COST2102), worth £325,611. This was a European research network (50 partners from 27 countries) co-ordinated by Stirling as grant holder.

Infrastructure and Facilities

The Division of Computing Science and Mathematics runs its own computing service, providing a high level of capability to all researchers. We employ two full-time computing support staff and one 50% technician. We have two clusters used purely for research, providing a total of 104 cores. In addition, the Division uses its teaching laboratories to provide parallel processing as they are largely free overnight and out of teaching semesters. This parallel machinery provides a total of 350 cores, and has provided an important resource for the modelling and analysis of complex systems and for simulations of epidemic spread. Further capability for parallel processing is provided through access to the ArchieWest system (Strathclyde), which has recently come on-line. The Division has three special-purpose laboratories specifically for research projects. One (partially funded by SRIF) houses an audio lab, with robotics equipment and a communications systems lab. The second provides a realistic environment for Home Care and Healthcare projects. The CHORDS laboratory provides high performance equipment for pursuing computationally intensive heuristics research. All are heavily used by our research groups. We also have Library and IT support including a dedicated Science-librarian on information-seeking tools. We are using the facilities provided by SICSA (e.g. DemoFest, and access to Edinburgh's large technical commercialisation capability) to develop better commercial and industrial links.

e. Collaboration and contribution to the discipline or research base

Close collaborations across universities, industry, commerce and the public sector play a critical role in our research strategy. Our strategic research goals place stakeholder engagement at the very heart of what we do. Examples of our collaborations have been described above and they clearly represent a dynamic and thriving research synergy across disciplinary boundaries and across stakeholder communities. Our research portfolio, described above, is almost entirely interdisciplinary, involving strong collaborations with other disciplines. We have a wide and diverse network of collaborations with other institutions (academic, industrial and public sector) across the UK, Europe and the World. These collaborations represent new ideas and innovations to drive exciting new developments that have a real societal impact. It is critically important to note that we are not simply providing 'Computer Science' input to other projects, but we are a primary partner, pushing forward the boundaries of Computer Science into other disciplines and re-shaping the international research agenda in the light of new inter-disciplinary synergies. Interdisciplinary research is fundamental to all that we do and it drives our strategic research agenda across all areas of our activity.

As mentioned above, since 2008, we have received funding from EPSRC, ESRC and BBSRC. This reflects the truly inter-disciplinary nature of our research. It also reflects our close synergy with RCUK priority areas and our aim of working in close partnership with colleagues at the research councils to engage with priority themes. The SICSA research pooling initiative has played a key role in driving inter-institutional staff and PhD student collaborations with other universities in Scotland. Shankland leads the SICSA theme on Modelling and Abstraction and this leadership has been instrumental in raising the international profile and major potential impact of research in this field. Our inter-disciplinary and stakeholder collaborations drive not only our research strategy; they also drive our impact strategy (see section 3a and the case studies). The realisation of our research impact relies on close stakeholder and inter-disciplinary collaboration at all stages of our research activity. Researchers at Stirling have demonstrated clear exemplars of research leadership in the academic community throughout the REF assessment period. Some

examples of this leadership activity are outlined below.

National/International Advisory Board Membership
Burke was a member of the EPSRC Strategic Advisory Team for Mathematics between August 2008 and March 2013. He is also currently a member of the Scottish Government Data Management Board and the Scottish Government Data Linkage Programme Board. **Graham** is a member of the Board of Directors of the Organisation of Computational Neurosciences and he is a member of the UK Node of the International Neuroinformatics Co-ordinating Facility. **Hussain** and **Smith** are founding members of the China-Scotland Signal Image Processing Research Academy comprising seven Chinese and four UK Universities. **Smith**, **Turner**, **Burke** and **Graham** are members of the EPSRC College. **Graham** is a member of the BBSRC Pool of Experts. **Norman** has been a member of panels for MRC, BBSRC, NSF and EU. **Smith**, **Kleczkowski**, **Hussain**, **Hoyle** and **Farkas** have all reviewed for the EU FP7. Staff in the UoA have reviewed research proposals for international agencies such as the Australian Research Council, the Dutch NSF, NSF, the Foundation for Polish Science, Research Grants Council of Hong Kong and the Swiss National Science Foundation.

Leadership in Industry
Hussain is chair of the IEEE UKRI Industry Applications Society. **Burke** has been a director of Aptia Solutions Ltd throughout the assessment period and he was a director of Staff Roster Solutions Ltd between 2010 and 2012.

Engagement with Learned societies
Burke is a Fellow of the British Computer Society, the Operational Research Society and the Institute of Mathematics and its Applications. He is also a member of the UK Computing Research Committee and he is Treasurer of the Committee of Professors in Operational Research. In addition, **Burke** was a member of the General Council of the OR Society during the assessment period and he was a member of the Jury for the EURO (Association of Operational Research Societies) Excellence in Practice Award in 2009 and 2010. This is the premier prize in Europe for high impact Operational Research. **Kleczkowski** is a Fellow of the Royal Statistical Society and the Institute of Mathematics and its Applications. **Graham**, **Hussain** and **Smith** are senior members of the IEEE.

Journal Editorships and Conference Programme Chairs
Hussain is Editor-in-Chief of Cognitive Computation and he is Series Editor of the Springer book Series on Socio-affective computing. He is also Associate editor of IEEE Transactions on Neural Networks and Learning Systems. **Burke** is Editor-in-chief of the Journal of Scheduling, Area Editor (for Combinatorial Optimisation) of the Journal of Heuristics, Associate Editor of the INFORMS Journal on Computing and Associate Editor of IEEE Transactions on Evolutionary Computation. He is also a member of the Editorial Board of Memetic Computing and he is a member of the Advisory board of the EURO (European Association of OR Societies) Journal on Computational Optimization. **Ochoa** is an Associate Editor of Evolutionary Computation. **Farkas** is a member of the Editorial Board of the Journal of Biological Dynamics and of the International Journal on Mathematical Methods and Models in Biosciences. **Burke** is Chairman of the Steering Committee of the International Series of conferences on the Practice and Theory of Automated Timetabling (PATAT). He was Technical co-chair of the 2012 IEEE World Congress on Computational Intelligence (IEEE WCCI 2012) in Australia, 10th-15th June 2012.

Invited keynote talks
Smith, **Graham**, **Burke**, **Hussain**, **Farkas** and **Turner** have given invited keynote talks at international conferences, including IJCCI 2013 (Portugal), BIOPRO 2011 (Taiwan), UKCI 2012, IJCNN 2013, ICONIP 2012, BIOMATH 2012, International Conference on networks 2009, NOTERE 2009, ISSNIP 2011, ECCO (Spain) 2010, Annual Conference of the OR Society (2009 and 2011), EURO XXIII (Bonn) 2009 and MISTA (Dublin) 2009.

PhD External examining
Since 2008, the following staff members have acted as external PhD examiners – with the number of occasions given in parentheses: **Hussain** (12), **Smith** (12), **Graham** (8), **Burke** (4), **Norman** (3), **Kleczkowski** (3), **Turner** (2).