Institution: University of Hull

Unit of Assessment: B11: Computer Science and informatics

a. Overview

The Department of Computer Science is part of the Faculty of Science and Engineering. Research within the Department is organised within three research groups: Dependable Systems; Intelligent Systems; and Simulation and Visualization. Each group has dedicated laboratory space with facilities to support research by academic members of staff, research associates, postgraduate research students, and visiting researchers.

Organisational and administrative structures for research are coordinated through the Head of Department, Director of Research and Research Group Leaders. A Research Committee develops and coordinates a cohesive research strategy and approves individual and group annual research plans. An annual review of current and potential research activities allows the monitoring of the quality and quantity of research, and guides future investment.

The transformation of research into enterprise is facilitated by both the Research and Enterprise committees. As a key component of the research strategy, SEED (the Department's commercial software unit) focuses on the transformation of computer science research into commercial reality.

The Department's computational infrastructure supports research information systems, enabling collaborative workspaces, and information pertaining to opportunities for research funding and publication.

b. Research strategy

The strategy is to concentrate all research into the three groups and pursue specific focused themes. The themes were selected to draw upon existing research expertise and to coincide with the research priorities of the Faculty, University and wider community. Support and investment is made available only within these themes. Research collaboration and team working is strongly encouraged. Staff development is available at the point of need. Seven new appointments have been made to reinforce the groups and strengthen the themes.

For RAE2008, a decision was taken to submit under UoA25 (General Engineering and Mineral & Mining Engineering), combining the research of several departments. This submission included three Computer Science staff (Phillips, Papadopoulos and Kambhampati). The Departmental Research Strategy (in place since 2005) of focusing research on certain key areas had yet to provide the strength for a bid under UoA23 (Computer Science and Informatics). Overall, the University was ranked 44th in RAE2008, with the UoA25 submission ranked 34 from 52. Positive comments include:

- The majority of research outputs were of internationally excellent or internationally recognised quality;
- There were broad sources of funding streams for research with cross-disciplinary grouping of predominantly internationally recognised quality. Evidence of excellent core skills translated across a broad range of industries;
- Esteem indicators were of internationally and nationally recognised quality.

The Department's strategy was developed so that certain key areas, e.g. Dependable Systems, Medical Systems including Telehealth, would become the focus for supported research, often pump-primed via PhD scholarships. Since 2008, the Department has made considerable progress in strengthening its research income, generating more high-quality outputs with a greater synergy and collaboration between staff within and across research groups. The University and Faculty have backed the research strategy with three professorial appointments and a number of new lectureships in the current REF period, as evidenced by five Early Career Researcher entries, strengthening all three research groups.

- 15 Staff entered for REF2014 in contrast to three in RAE2008.
- An increase in number and quality of outputs across the Department with two case studies showing evidence of research impact.
- Research income of over £2.1M with several high-profile grants, much improved from 2008. Largest single funder is the European Union, with UK industry, Research Council and UK

health authorities also providing significant funding.
- 24 PhD degrees awarded during the period, with FTE figure closely matching the RAE2008 UoA23 average, and higher than the median figure.

The Dependable Systems group (DS), led by Papadopoulos, focuses on developing novel techniques and tools to improve the quality and dependability of systems via advanced safety and reliability analysis, multi-criteria design optimisation, testing, and assurance of data integrity. DS is currently funded by EPSRC, European Commission, and in various forms (research contract, consultancy, licensing of tools) by Research and Development departments in Volvo, Honda, Continental, Flemish Mechatronic Institute, Embraer and Germanischer Lloyd, among others.

The Intelligent Systems group (IS), led by Jiang, aims to carry out well-balanced research work on both theoretical exploration and practical applications for mutually inspired innovation. It focuses on three main areas of research: Applied Distributed Information Systems (ADIS); Cognitive and Control Systems including Robotics; Decision Support and Data Mining in Telehealth. The latter includes research on decision making and data mining from clinical data, machine learning and pattern recognition, and pervasive intelligence provided by wireless sensor networks for Telecare and other industrial applications. IS now looks to combine the work on ADIS within telehealth research. Robotics work is evolving to provide advanced research into robot assisted telecare. IS continuously publishes research findings in top academic journals and conferences. In addition to academic research, IS has a strong capability for practical product design and development for local industrial companies.

The Simulation and Visualization group (SimVis), led by Wright, focuses on the application of simulation and visualization environments to genuine end-user problems, and the new tools, techniques and theory needed for their construction. Its particular strengths in underpinning technologies stem from work on novel systems and algorithms for modelling, simulation and rendering, and expertise in building, validating and using innovative display modalities. These combine into discipline-leading applications in radiotherapy training, radiological interventions, visual media and the environment. The strategy for ensuring a reputable and sustainable future for the group is to carry out evidence-based, fundamental computer science research that is grounded in the real world of users' needs and aspirations.

c. People, including:

i. Staffing strategy and staff development

The Department has organised its research groups so that staff interact to apply their expertise to the major research themes within the Faculty of Science and Engineering, namely: telemedicine, telehealth and medical systems; transport; energy and the environment. The staff loading model favours research in these areas. Since 2011, the Department has welcomed five (early career) lecturers, three new professors (Hawick, Jiang, Papadopoulos), and seen the promotion of existing staff, based on their research leadership. All staff appointed are included in this REF submission, as they are research active with good publications, and promising research careers. These new staff and promotions build and strengthen the existing research groups. All new staff are supported by Faculty PhD scholarships. Research theme targeted (Departmental and SEED) PhD studentships, plus research grants, such as HEIF5 Telehealth projects, are used to pump-prime collaborative research across the Department and beyond. To foster and develop the research culture within the Department, research and enterprise activities form part of the Department's workload model. Research activities, such as postgraduate student supervision, research grant submission and management, and research output submissions are used as factors to balance research, teaching and administrative requirements across the Department's academic staff.

The University, in accordance with the Concordat to Support the Career Development of Researchers, recognises and promotes the importance of researchers' personal and career development and lifelong learning. As well as encouraging researchers to identify and attend events contained in the annual career development programme, the University offers nationally recognised courses for researchers run in-house. Research project supervisors are encouraged to use it, along with their associates and students. The Researcher Development Framework (RDF) is a detailed competency framework that maps out the skills required to be a successful researcher. Research staff use the RDF to plan their own development in conjunction with appraisal and review discussions. The Staff Development Unit assists with the RDF and runs

focused briefing sessions and more extensive workshops on using the framework with case studies of effective practice. In addition the Department, and each research group, provides development activities, and peer reviews of research plans and project outlines

During the period, international visiting staff appointments (incoming and outgoing), include:

- Trung Chi, *Technology Enhanced Learning in Computer Science*, funding from Hanoi National University of Education, Vietnam, 01/09/2011 to 30/01/2012 (IS Group – Gordon)
- Dr Deqiang Chen, *Locality Sensitive Hashing for Memory Based Learning*, funding from Shanghai Municipal Education Commission, 01/02/13 to 31/01/14 (IS Group – Jiang)
- Mr Can Zhao, *A wearable sensor system for healthcare of the elderly*, funding from iMonSys Ltd, 01/07/13 to 31/12/13 (IS Group – Jiang)
- Professor Feiyue Qiu, funding from China Scholarship Council and Zhejiang University of Technology, 01/02/2010 to 31/07/2010 (SimVis – Li)
- Professor Xie Han, funding from Shanxi Provincial government and North University of China, 01/03/2011 to 30/03/2012 (SimVis - Li)
- H Wright, Visiting Fellow, 23 July – 3 August 2012, £1695 from Pontifica Universidad Javeriana, Cali, Colombia. Kickstart VE and Visualization Research of the DESTINO group; International Advisor, ongoing from July 2012.

The University of Hull is committed to equality of opportunity and respecting diversity for both staff and students. To support this and raise awareness about equality and diversity, training opportunities ranging from online modules to bespoke training packages are offered by the University's staff development team. All staff interviewing PhD applicants, researchers and other academics must have completed the required training. The Department has a Staff Development Officer to ensure that training on this and other aspects are publicised and taken up. This and other training issues are also addressed during the annual staff reviews.

ii. Research students

The department nurtures a strong research ethos and culture for postgraduate research students. During this REF period the Department has awarded (24) PhD and (3) MSc research degrees. At census point, there are 16 registered postgraduate research students (with six further expected to join this year) placed in one of the three modern open-plan (24-hour access) research laboratories associated with the three research groups. Where possible, the Department recruits outstanding individuals as PhD students from its undergraduate and postgraduate taught cohort. International research collaborations are a further source of PhD candidates. All PhD students are funded to at least EPSRC levels using University and Faculty PhD scholarships, Departmental and SEED PhD studentships and research grants. An increasing number of students are funded through the China Scholarship Council. All research student supervisors attend the University level Graduate School training courses, with continuing professional development provided for more experienced supervisors. The Director of Postgraduate Research and the Postgraduate Research Training Officer ensure that both students and staff are aware of best practice and changes in processes with intranet document support provided. The Director of Postgraduate Research is supported by a dedicated member of the secretarial team, acting as point of contact for admissions and student queries.

A research student is supported by at least one main supervisor, a supervisory team of at least three academics, dedicated research officers and a training programme tailored to the individual needs of the research study. The supervisory team offers advice on a continual basis, ensuring that progress is good, the research is focused and any training requirements are identified and met. PhDs programmes are structured with a clear set of goals and deliverables for each year of study. These are formally reviewed via four PhD Panel meetings (with the supervisory team) over the course of the study; each with mandatory and discretionary deliverables:

- Week 16 PhD1 – Project Topic Analysis meeting: Panel reviews and advises on the proposed research programme. Additional deliverables (if any) for the PhD are agreed for the first year of PhD study.
- Week 48 PhD2 – First Year Review meeting: Panel advises and reviews progress against previously agreed deliverables. Transfer to MPhil or MSc programmes can arise in the case of poor progress. Additional deliverables (if any) are agreed for the second year of study.
- Month 22 PhD3 – PhD Transfer meeting: Panel advises and reviews progress based on an

oral presentation, work accomplished, two draft chapters of thesis, a plan of the thesis and a plan of remaining research work. Panel recommends continuance on PhD or otherwise. Additional deliverables (if any) are agreed for the last year of study.

- Month 30 PhD4 – Thesis Review meeting: Panel reviews draft chapters of the thesis and publications (e.g. journal papers, conference papers, conference presentations, etc.).

All research students must complete the Postgraduate Training Scheme run by the Graduate School (GS). The GS is an on-campus purpose-built facility with 24-hour access for research students and their supervisors. Both an administrative centre and a resource, with its own IT and common rooms, the GS oversees a rigorous annual monitoring of research students' progress, and liaises with all University Faculties and Departments on matters concerning research students. The Postgraduate Training Scheme enables students to graduate with certificated evidence of their research and transferable skills. Interdisciplinary modules offered include 'Managing your Research Degree', 'Career Management Skills for Research Students' and 'Enterprise and Entrepreneurship Skills'. An annual 'PhD Experience' conference, organised by students, is hosted by the GS. An innovative online Graduate Virtual Research Environment has assembled the collective stories of researchers and research students across the University, enabling students to access over 200 short videos illustrating individual research achievements and advice on all aspects of the research degree journey.

The research environment is enhanced by a programme of PGR presentations in colloquia and the Department's own annual Postgraduate Research Poster Conference. In addition, the students run their own Postgraduate Forum to foster social activities and networking. The Department supports weekly held research seminars and colloquia which all PGRs are expected to attend. These allow for cross-fertilisation of ideas with presentations by external speakers, members of staff and postgraduate research students. All MSc by research students present one colloquium over the course of their studies, while PhD students are expected to present two – one after their first year of study, and a second around the time of completion.

Participation in national meetings, international conferences and journal writing is expected, supported by a Departmental Travel Fund. This is embodied in the Department's PGR objectives, as part of the University's Postgraduate Training Scheme, and the Department hosting its own annual one-day conference. As much work is multidisciplinary, PGRs frequently participate in seminars and events hosted by other Research Groups, e.g. the University Centre for Telehealth, Medical Engineering, Academic Cardiology, etc.

A number of PhD students have been awarded 'distinctions and best paper awards' at International peer-reviewed conferences, e.g.: Amer Dheedan, best paper at EMERGING12; Mostafizur Rahman, best paper at ICDMKE12; David Parker, distinction at SAE09; Nidhal Mahmud, distinction at ARES11; Septavera Sharvia, distinction at DEPCOS'10 and ICCSIS'09. Our students apply their research in case studies from industry by exploiting the reach of the HiP-HOPS technology (see impact case) and extensive collaborations with global industry. More than 50% of student research output is the result of productive collaboration with industry. Many students work on projects that contribute to important developments in Europe, e.g. the specification of the EAST-ADL automotive language.

d. Income, infrastructure and facilities

The Department hosts three dedicated research laboratories, a robot laboratory and HIVE. Since 2008, the department has invested over £80,000 in the renovation of the research labs.

Library and Learning Innovation's (LLI) role is to support, improve and transform the teaching, learning and research environment of the University of Hull. LLI, together with the Research and Enterprise Office and the Information and Communication Technology Department (ICTD) provides activities and services supporting research and researchers, including research grant applications and the management of awarded projects. With the advent of Research Data Management, this includes advice and guidance on the management of any digital materials emanating from research, specifically the management and dissemination of research outputs via open access, and the planning and management for research data from inception through to archiving. LLI and ICTD combine in the management, dissemination and preservation of research outputs, both publications and data, through the Hydra institutional digital repository, in liaison with the Converis research information system.

The Department has attracted numerous funded Research Projects during the REF period, with current research spend at over £2.1M. The funded projects fall within our research groups and align with our research themes.

Major projects and funding within Dependable Systems are SAFEDOR (FP6 €320,000, 2006-2009), ATESST2 (FP7 €230,000, 2008-2010) and MAENAD (FP7 €298,000, 2010-2013). Papadopoulos, Walker and Parker have done consultancy on HiP-HOPS for the Flemish Mechatronics Institute in Leuven. The research associated with HiP-HOPS is now being applied to Telehealth systems. This research, across DS and IS, into mobile and distributed telehealth systems, will enable health provision to become more efficient and effective.

The total amount of funding income in Intelligent Systems since 2008 is around £1M, with EU and national research councils providing the core, and the rest from industry. Examples include Creating Trust through Digital Traceability (EPSRC £250,882, 01/04/2013 for 1.5 years), BraveHealth (FP7 £302,761, 2010-2013), and Advanced Medical Informatics (Philips Healthcare £69,299, 2011-2013). The robot laboratory has over twenty mobile robot platforms, embedded system development kits, computer vision, and other sensors. Planned Faculty investment (of around £50,000) will lead to the robotics work being developed for telecare applications, with great potential benefits to society. Ambient and Robot Assisted Living aims to overcome physical impairments, cognitive deficits, and social isolation with environments for the infirm and disabled.

SimVis funding comes from a range of sources: EPSRC, Wellcome Trust, Department of Health, HEFCE, Smith & Nephew. Particular project highlights are the CRaIVE virtual environment (VE) for interventional radiology (EPSRC £545,000, 2006-2010) and ImaGiNe-S VE needle access procedures (Health Technology Devices £162,000, 2006-2009). CRaIVE was a major collaboration involving five other universities with total funding in excess of £1.8M and leading VE company Virtalis as the industrial partner. In ImaGiNe-S, the same consortium teamed with Medic Vision to develop a pre-market simulation which was specifically praised in the Eurographics 2009 Medical Prize citations. In the '3D Virtual Wind Turbine' project (HEIF5 £240,000, 2012-2015) SimVis is applying this experience anew to off-shore training and working at heights, having built one of only six UK university-based CAVE-like displays.

SimVis research is facilitated by the Hull Immersive Visualization Environment (HIVE), Yorkshire and Humber's premier centre for virtual reality practice and research. HIVE was established in 2002 as a SRIF-funded initiative designed to leverage the quality and quantity of multi-disciplinary research, and is managed by a full-time member of staff. Facilities include a large rear-projected stereoscopic 'workwall' with head-tracking capability for collaborative projects, a range of fixed and portable stereoscopic immersive systems, and force-feedback displays. In addition to the newly installed CAVE-like display built using a HEIF5 award, in 2013 the Faculty of Science and Engineering is funding a £60k refresh of the original HIVE workwall as part of its capital refurbishment programme.

e. Collaboration or contribution to the discipline or research base

All staff entered in this REF submission are in demand for reviewing papers and research proposals, and to serve as external examiners of research theses. The VERT case study primarily addresses Computer Graphics (ACM 26) and Life and Medical sciences (ACM 28). The HiP-HOPS Impact case study and associated research addresses Software Safety and Software Reliability (ACM 7), System description languages (ACM 8) and Software Verification & Validation (ACM 9). The interdisciplinary nature of our research impacts also across other ACM Specialisms, most notably Model-driven software engineering, Fault-tree analysis, Computer Vision Problems, Computer Graphics, Visualization and Artificial Intelligence.

Within Dependable Systems, Papadopoulos has been visiting professor at KU Leuven, (December 2011) and Fraunhofer IESE, (April 2011). He is a member of the editorial board for International Journal of Discrete Event Systems Control (ISSN *2230-990X*) and the board of EAST-ADL association, a body responsible for evolution and maintenance of EAST-ADL architecture description language (www.east-adl.org) that is gaining prominence in automotive research and sector. Group members sit in two IFAC committees: TC 1.3 (Discrete event and hybrid systems) and TC 5.1 (Manufacturing Plant Control), and have leading involvement in networks and conferences that advance research in the field. The group has co-hosted DCDS'2013 (http://dcds13.net.dcs.hull.ac.uk/), the 4th IFAC Workshop on Dependable Control of Discrete

Systems, which Papadopoulos co-chaired.
IS group contributes to the University's Centre for research collaborations and interdisciplinary research on telehealth which brings together expertise from academia, primary and acute care, local authorities, industry and third sector partners to present beginning-to-end telehealth solutions based around specific clinical need. This includes, e.g., the FP7 Network of Interest SemanticHealthNet (http://www.semantichealthnet.eu/), which draws on the expertise of Davis and Kambhampati in applying advanced informatics technology to cardiovascular disease. The IS group has an extensive range of collaborations with national and international research institutions. The collaborations include exchanging researchers, seminars and international joint projects; Jiang has been invited professor in two prestigious Chinese universities, Tongji University and Xi'an Jiaotong University. Members of IS group are involved in international academic activities and regularly take part in the organisation of international conferences, e.g., as general conference chairs for IEEE Conference on Computer Science and Automation Engineering and IET Conference on Information Science and Control Engineering. Members of IS group are on the editorial boards of several international journals. Four keynote speeches and seven invited talks have been delivered in conferences and other institutions since 2008.
Members of the Simulation and Visualization research group contribute to and have been recognised in diverse ways within the discipline: Li is a member of the editorial boards of the journals *Computer Science and Engineering* and *Computer Science and Systems Biology,* has collaborated closely with the Intelligent Medical Research Center at the Institute of Automation, Chinese Academy of Sciences, and is a visiting professor of the North University of China; Ward is a founding member and now managing director of Vertual Ltd, and a member of the Institute of Directors; Viant is an advisory board member for Sony Computer Entertainment (Europe); Wright was coordinator of the EPSRC network 'CompuSteer', and is a member of the Numerical Algorithms Group Ltd. The work especially in Medical Systems is widely recognised with Vertual's radiotherapy simulator, VERT, winning prizes in the current REF period from Eurographics (2011) and Medilink (2008).