Institution: Coventry University

Unit of Assessment: 11

a. Overview

The Unit's research reflects a commitment to the development of software and systems which solve real world problems. There are three groups:

A. **Distributed Systems and Modelling (DSM) – Chao, James, Anane, Wang**
B. **Intelligent Systems (IS) – Petrovic, Iqbal, Doctor, Eastwood, Palade**
C. **Serious Games (SG) – de Freitas, Dunwell, Hendrix, Petridis**

b. Research strategy

i. Evaluation of Current Position with Reference to RAE 2008

Since 2008, a new research strategy has been developed which focuses on improving the quality of research, increasing the number of PhD students, increasing funding and targeting new interdisciplinary research areas. Intelligent Systems (IS) and Serious Games (SG) are new groups that have formed since 2008, whilst Distributed Systems and Modelling (DSM) existed previously. Since RAE 2008, the Unit has increased its external income nine-fold (see section dii) and its PhD completions by 66%.The following sections describe the major research achievements for each of the groups during the census period.

(A) Distributed Systems and Modelling: Since 2008, the DSM group has developed its research in service-oriented and distributed computing [e.g. **KMC1,3,4**; **RA2,3; AJ1,2**], information retrieval [**AJ3**] and grid computing [**AJ4**]. **Chao**'s research resulted in the development of the first ontology of household appliances. This work forms the basis for one of our case studies (DEHEMS) [**case study 11.2**]. Additionally, **James** has developed an ontology of exceptions in multi-agent systems (MAS) and an exception handling agent for MAS [**AJ1**]. An evaluation the agent-based approach has been carried out by **Anane** in the context of a manufacturing environment **[RA4]**. **Chao** has also carried out research in the area of discovery, composition and selection in web services [**KMC1,3,4**]. He has developed a model which assists consumers in selecting the best web service for their needs. It supports identification of the differences in services and assists service consumers in selecting the most suitable with consideration given to expectations and preferences. Further innovative work in web services has been carried out by **James** in the area of transaction handling [**AJ2**]. In her research the issue of applying a centralised management approach to distributed services was resolved through the development a customisable framework which offers selective enforcement or relaxation of controls. In the area of network service quality, **Wang** has investigated delay sensitive applications and developed a novel analytical model for the relationship between the queuing threshold and average queuing delay [**XW3,4**]. The approach enhances the performance of delay sensitive applications.

(B) Intelligent Systems: Petrovic has developed a novel coordination method for the distributed supply chain (DSC) which is based on the fuzzy multi-level optimisation method [**DP2,4**]. New models of continuous-review inventory control in the presence of uncertainty have also been introduced [**DP1**]. **Iqbal** has carried out the first comprehensive attempt at addressing task-specific information retrieval needs of software engineers [**RI4**]. The area of theoretical machine learning has been addressed by Palade **[VP1]** and a solution to the structural risk minimization problem has been produced. **Palade**'s research has led to the microPred classifier for human miRNA gene prediction, which is more reliable than other classifiers [**VP2**]. He has also addressed the problem of class imbalance for Fuzzy Support Vector Machines (FSVMs). The proposed solution has been thoroughly validated on several real-world imbalanced datasets [**VP3**]. **Palade** has also shown that the quantum-behaved particle swarm optimization algorithm can converge to a global optimum [**VP4**]. **Doctor**'s research has included intelligent affect-aware behaviour modelling and control in the field of dementia monitoring [**FD1**] and the related development of a neuro-fuzzy embedded agent for ambient-intelligence as a system on a chip [**FD2**]. **Eastwood** has carried out research resulting in a method to simplify and combine the structure of multiple decision trees [**ME1**].

(C) Serious Games: The group has investigated digital games technology in different sectors using a wide range of methodological approaches, including pragmatic and cluster randomised

controls, social network analyses, heuristics for usability studies and intervention mapping techniques. The research resulted in the creation of a new pedagogic model, framework and metrics for improving efficacy of game-based approaches [**SdF1,2**]. The resulting model, framework and metrics have been used in a number of EU FP7 projects to design learning outcomes and curricula [**SdF3,4**]. Further research in virtual reality [**PP1**] addresses the necessity for balancing computational efficiency with the requirement to provide believable and interactive virtual characters, allowing varying degrees of visual, interactive and behavioural fidelity. The area of games repurposing has also been explored [**PP2**]. The research results have also been applied in the design and development of a virtual reality Construction Site Simulator for off-site production [**PP3**] where core concepts and strategies were identified and thoroughly evaluated. Other achievements include the development of a new method to simplify the problem of manual annotation in hypermedia authoring systems [**MH1**] and the introduction of a novel paradigm of collaborative complex learning objects (CC-LO) [**ID1**] which can capture and merge heterogeneous concepts from diverse learning content providers.

ii. Research Vision and Strategic Plans

Our vision over the next six years is to produce excellent research which addresses relevant challenges within our fields of expertise. To facilitate the vision, expansion of the groups will take place. Each group will recruit an experienced or early career researcher, a post-doctoral researcher and three new PhD students per year. Funding for this will come through internal University support and external grants. Please see section dii for the funding strategy.

(A) Distributed Systems and Modelling: The group plans to:

- build on current research [**KMC1,3,4**] in developing methods for service representation, discovery, selection and composition. Computational resources and data in the cloud can be modelled and represented as services, so they can be discovered and evaluated for reuse and sharing. Artificial intelligence will be exploited to increase accuracy in annotating and summarising data and characterising resources to effectively automate the process of service discovery and composition.
- develop an innovative platform for virtual meetings incorporating intelligent support for conversations. There are many virtual meeting support systems available but none represent the meeting structure in a comprehensive way. Building on previous research [**AJ1**, **RA4**] an intelligent virtual meeting system based on agents will be developed which will understand the semantics of the collaboration and thus control and aid the progress of the meeting. The research will involve classifying meetings, building canonical ontologies and building an agent-based virtual meeting system to evaluate the theoretical design.
- develop improved methods for middleware for parallel processing. Building on previous work [**AJ4**] a parallel scheduler for grid applications will be developed making a contribution to methods of developing parallel software for middleware applications and in particular improving the efficiency of grid scheduling.

(B) Intelligent Systems: The group plans to:

- develop a new interdisciplinary, system-based framework for management and control of complex sustainable supply chains in the presence of various risks and sources of uncertainty. Building on the research already carried out [**DP1,2,3,4**], optimization methods will be developed to handle social, economic and environmental aspects of sustainability.
- develop novel intelligent systems for modelling and identifying physiological and emotional responses to enhance monitoring and control aspects of ambient intelligent environments. The research builds on current achievements [**FD1,2**] and aims to develop new ways of modelling, learning and affecting the users' emotional states through the use of intelligent affect-aware systems and services.
- build on current research [**RI4**] and develop task-specific search utilities by conducting empirical studies and balancing technical aspects with human factors. Jaguar Land Rover is contributing to this research by offering test beds as well as financial support.

(C) Serious Games: The group plans to:

- develop new metadata standards for games, including work with next generation SCORM and IEEE standards bodies to ensure that game content can be re-purposed on different game engines and e-learning platforms. This builds on previous research [**PP2**] and will

include the development and testing of a meta-feedback model for serious games interventions based upon the four dimensional framework [**SdF2**], which will be used in health and well-being, business engagement, leadership training and primary education.

- develop an innovative service framework, blending the technologies of smart networks, social networks, virtual worlds, enabling the user to visualize, monitor and manage environments, whilst gaining immediate feedback through interactive interfaces. The proposed system builds on previous research [**ID1,MH1**] and aims to simplify the creation of collective intelligence from industry standard data streams and present the information to the user using well-established modelling frameworks but through a variety of interfaces.

c. People, including:

i. Staffing strategy and staff development

The University is using the nineteen agreed measures of progress drawn primarily from the Careers in Research Online Survey (CROS) and the Principal Investigators and Research Leads Survey (PIRLS), to implement the principles of the **Concordat** to support the career development of researchers. The University was awarded the European HR Excellence in Research Award in January 2013 and the Athena SWAN Bronze award in September 2013. The University is also a Stonewall Diversity Champion. Current priorities include developing a new web-based researcher career development portal and the extension of the researcher progression ladder.

Recruitment and Promotion: The research leadership in each theme has been strengthened with the promotion of existing staff to professorial posts [**Chao**, **Petrovic**] to complement the existing leadership [**de Freitas**, **James**]. Following external competition new appointments have been made: to Reader [**Palade**] and new Early Career Researchers [**Doctor, Eastwood, Petridis, Dunwell, Hendrix**]; and tenured staff have been promoted (for instance **Iqbal** to Readership). There is an open promotion scheme in which any member of academic or research staff can apply for promotion from Lecturer grade through to Professor or from Research Assistant through to Senior Research Fellow. Unconstrained by budget, promotion is based on clear criteria and for Readers and Professors is subject to external peer review.

Early Career Researchers (ECRs): New appointees are assigned mentors and probationary supervisors. The groups allocate funding from RAE 2008 QR to help ECRs with conference attendance and travel. This funding has also been used to create PhD studentships so that ECRs can take leading supervisory roles. New academics have reduced teaching loads of 20% for the first two years of their appointment. ECRs receive additional support in preparing research grant applications and in submitting articles for publications. Normally their mentor will publish and bid with them in the first year. For example, in 2008, **Iqbal** was an ECR and received such support. He now is a Principal Investigator and has been promoted to Reader. Support is also provided through seminar series', reading groups, formal research publication plans and networking plans. This Unit has an exchange scheme with European Universities where ECRs visit other research groups for short periods. During the census period **Petrides**, **Dunwell** and **Hendrix** exchanged with ECRs from the Universities of Toulouse, Skövde and Aachen.

Career Development: All staff have an annual development review which sets research targets, provides personal feedback and identifies career development and tailored workload planning needs. The staff development programme provides opportunities for acquiring or consolidating interpersonal, research management, and research leadership skills. For example, **de Freitas** enrolled on the Entrepreneurial University Leadership Programme as part of her staff development objectives. The University-wide research staff development programme includes topics such as bidding, academic writing, PhD supervision, and peer review of research. This routinely involves bringing in external experts, staff from funders as well as experienced bid writers. Funding from research grants, from RAE 2008 QR and previously from the Royal Society has been used to support conference attendance for networking and dissemination. The University also has a sabbatical scheme which enables researchers to apply for and take between three and six months out of normal duty in order to concentrate on research.

Outgoing International Collaboration and Networking: The University's Applied Research Fellowship (ARF) scheme allows researchers with clear research collaboration plans to receive up to £10,000 funding to make multiple visits over one year to international universities. **Doctor** has used the ARF scheme to visit two prominent institutes in Taiwan (Yuan Ze University and

National University of Tainan) in order to develop collaborations. **James** has visited the University of Wuhan, China, the University of Fudan, China and the University of Magdeburg, Germany.

Incoming International Collaborations: The Unit usually welcomes around 30 international visitors each year as part of structured plans to increase the international networking and industrial collaboration opportunities for staff. For example, the SG group routinely hosts collaborators from active collaborations with Graz University, George Mason University, Princeton University and the National University of Singapore. The University provides funding to attract International Visiting Professors (IVPS) and Industrialists in Residence (IIRS). These are available on an open call basis to support the development of long term collaborations. In 2012 the IVPS provided support to host a visit by Professor Paddy Krishnan of Bond University, Australia to the DSM group and in 2013 the IIRS scheme provided support to host a visit from Dr Zeeshan Usmani, Chief of Research, Interactive Group, Islamabad, Pakistan to the IS group to collaborate on the development of intelligent systems to counter terrorism.

Research Seminar Series: The groups have vibrant seminar series' which occur monthly. The aim of each seminar series is to share research with internal and external colleagues and to develop networks which can form the basis for future collaborations. The series' has included speakers from Unilever R&D, University of Salford, University of Exeter, King Saud University, Saudi Arabia, Bond University, Australia and University of Ruse, Bulgaria. In addition, the Unit operates a monthly 'Second Wednesday' event which brings together researchers and practitioners to discuss areas of common interest and identify potential collaborative projects. The event series has been sponsored by NESTA, BAFTA and the European Commission.

ii. Research students

Creating an effective and supportive environment for research students is a core element of the Unit's philosophy. This begins with careful recruitment of potential students to self-funded, University, or externally sponsored studentships. All students are required to meet qualification and English language thresholds, provide references and write a research proposal. Students are also routinely interviewed to assess their suitability to join the research groups. The research groups also identify promising students from the undergraduate and postgraduate courses and involve them in research through project work and summer internships funded by Nuffield as well as through faculty-funded graduate internships. Currently six PhD students have been recruited in this way.

Studentships: The Unit invests in fully-funded PhD studentships to build research capacity and support research supervision among early career staff. The studentships are awarded competitively and are funded equally by the University, Faculty and the RAE 2008 QR funds. There have been seven full-time UK/EU studentships awarded during the census period.

Integrated Research Culture: Research students are normally accommodated close to their supervisory team to ensure frequent communication. There is an ethos in the research groups of encouraging research students and supervisors to prepare and submit joint papers and involving students in international networks and conference organisations. Twenty per cent of the total refereed publications of the Unit during the census period were co-authored by research students.

Structure Supervision, Training and Monitoring: Since 2008, the University has built a new and comprehensive PhD support infrastructure and training programme. The framework programme gives coherence by scheduling research and written deliverables approximately every four months. Progress reporting and monitoring is recorded centrally on the student record system. In addition, 40 credits worth of taught modules in research methods and specialist research techniques are studied during the programme. All students have a formal entitlement document which specifies minimum supervisor contact time, accommodation, personal computer, storage, printing and financial support available for conference attendance and incidental purchases. At the end of each 12-month period, research students undergo a formal Progress Review Panel (PRP) presentation and viva with independent subject-matter experts. During the census period the number of doctoral students enrolled has grown from 12 (8 full-time, 4 part-time) in 2007-2008 to 38 (32 full-time, 6 part-time) in 2013-2014. This increase in enrolments has been gradual over the census period therefore completions, whilst having increased by 66% since 2008, are not yet matching 250% (10 FTE to 35 FTE) increase in enrolments.

Seminars, Symposiums and Competitions: PhD students organise and attend weekly

seminars to discuss research issues and there is an annual student symposium at Faculty and University level at which doctoral students make presentations about their research. Students have the opportunity to enter competitions and events with students from other universities at national and international symposiums. This helps to develop their presentation skills and encourages them to build research networks. Some of our research students enter an annual competition with students from the University of Warwick. During the census period all research students have taken part in at least one of these events.

Career, Leadership and Entrepreneurial Support: The Graduate Centre organises non-assessed training workshops for PhD students. These workshops are supplemented by the suite of Epigeum online research training materials which can be accessed through the research student Moodle site. Students also have access to the dedicated training and support from the Enterprise and Careers Support Team which provides targeted support on graduate careers, business start-up, finance, IPR and access to equity.

Student Exchanges: There are opportunities for research students to exchange within partner institutions. In the last three years, exchanges have taken place at University of Fudan, China and University HUST, China. During these exchanges students work on their PhD programmes and have the benefit of idea-sharing and guidance from international collaborators, thus broadening their perspectives.

d. Income, infrastructure and facilities

i. Infrastructure

The DSM and IS research is based in the new Engineering and Computing building (developed through capital investment of £55 million and opened in 2012) where there is access to speciality servers, software and simulation facilities to support cloud-based and service-oriented computing. The researchers and research students typically each have their own desktop and laptop and also have full access to a High Performance Computing (HPC) facility. This recently upgraded facility comprises a cluster of 176 computer nodes interconnected with QDR high speed infiniband bus (40Gb per channel). Each node has an 8-core Xeon CPU, 48 GB of RAM and most have 125GB SSD (solid-state disk) drives for local storage. In addition the HPC has 18 GPU nodes, which have two 6 core Xeon CPUs and two of the latest Nvidia Kepler family K20 GPU processors which deliver more than a teraflop of peak double precision performance. There is one dedicated node for symmetrical multiprocessing jobs comprising of 32 cores and 512GB of RAM. Including management nodes, there are 1900 cores, a total of 10TB of RAM and a peak performance of 56 DPTFlops. This facility provides enough computing performance for postgraduate students and research staff. A total of £654k has been spent on HPC hardware since 2008. In addition to this facility the students and staff are equipped with the latest desktop technology and the DSM group has a cluster of Pentium i7 computers which it uses for additional exploration in cloud and distributed computing. A team of technical and project officers maintain computing and laboratory infrastructure.

SG research is based in the Serious Game Institute funded through £7 million capital funding from the West Midlands Regional Development Agency. It is a dedicated building with research space and incubation facilitates for start-up and medium sized companies specialising in games and virtual worlds. The research facilities include a Serious Games Studio, Mobile Applications Laboratory, a dedicated teaching laboratory, research floor, space for companies, business incubation facilities and a showcase area. It has various state-of-the-art hardware and software including brain computer interfaces, haptic devices, games development software and servers. Near Infrared Spectroscopy (NIRS) and Electroencephalography (EEG) scanners are used to support research in game-based comparative studies. Researchers also use facilities for testing at Imperial College (NIRS scanner and eye tracking system with dedicated software) and Graz University (EEG and eye tracking hardware with specialist tracking and analytical software) in collaborative research and experimentation centring upon psycho-neurological studies of medical staff and student populations. Students also have access to facilities at VeraCruz University, Mexico and North West University, South Africa through overseas research partnerships (see serious games **case study 11.1**).

ii. Research Funding Portfolio

Funding Strategy: The aim of the external funding strategy has been to support and grow

research capacity by focusing on those areas of applied research that are perceived to be most needed by the economy and society. This has been achieved by focussing on grand challenges set by the University. The net result is that annual income for this Unit has grown from a total of £419,070 in the last census period to £3,762,211 in this census period. Over the current census period this Unit has obtained 16 EU grants, 3 TSB grants and 3 MOD DSTL grants.

Funding Support Resources: The Unit has benefitted from the University's Business Development Support Office (BDSO) infrastructure. The central BDSO provides comprehensive research funding identification, bid writing, bid appraisal, training, project management and financial support to researchers. BDSO support is provided by a team of 60 Business Development Managers/Officers and Research and Finance administrative staff, who assist with the grant proposal process, and with the management of funded projects.

Future Funding Plans: The aim is to grow the external funding for this Unit from circa £0.75 million per year to £1.5 million per year by 2020 to maintain and grow the research activity. The intention is to underpin the sustainability of the research groups both in terms of funding and in terms of access to relevant communities by:

- Increasing the number of large grants covering multidisciplinary areas to provide critical mass, flexibility and outcomes with potential for wide application. For example, the Unit has recently achieved success on a number of large multi-disciplinary EU FP7 programmes and EPSRC calls: advanced technology based business approaches (FP7, FLEXINET, 2013-2016, €369,889); game technologies for future manufacturing (EPSRC, Servitization, 2013-2018, £477,591); intelligent digital household network (EPSRC, BuildTeddie, 2013-2018, £669,209); and web platform for creativity support (FP7, MAGELLAN, 2013-2017, €387 000).
- Increasing the number of medium sized interdisciplinary grants, for areas such as integrated supply chain planning and collaborative computing. For example, the Unit has recently obtained medium-sized interdisciplinary EPSRC and FP7 grants: resilience and robustness of dynamic manufacturing supply networks (EPSRC, Mathematical Sciences for Manufacturing the Future, 2013-2016, £213,210); ICT technologies to promote healthy lifestyle (FP7, PEGASO, 2013-2017, €261 000).
- Exploiting synergies between the groups to provide specialist consultancy in order to cross-fund and develop research activities. For example, researchers from the IS and DSM groups are working together with Jaguar Land Rover in the development of innovative software for on-board predictive systems. Collaborative bids to the Technology Strategy Board and EPSRC are planned as well as direct funding for research from Jaguar Land Rover.

e. Collaboration or contribution to the discipline or research base

The Unit's strategy for collaboration is to be outward-facing and engage with national and international policy makers, funders, academics and industrialists in order to identify and create a vibrant research environment.

Examples of National and International Research Direction: de Freitas is a member of the EU Working Group of Future Internet and Scientific Co-ordinator of the FP7 EU Network of Excellence in Serious Games (GALA). She also sits on the steering group of the Creative Industries Knowledge Transfer Network. **Palade** is a Co-Chair of the IFIP (International Federation for Information Processing) Working Group on Computational Intelligence TC12.9. **Iqbal** has been a member of the Undergraduate Research Bursary Scheme of the Nuffield Foundation since 2007. Members of this Unit also review proposals for funding authorities, for example: the EPSRC (**Petrovic**, **James, Palade**); the European Commission (**de Freitas, Palade**); the Medical Research Council (**Palade**) and the British Council (**Petrovic**).

Examples of Editorial Board Membership and Related Activity: The Unit has held 26 editorial board memberships during the census period. **Chao** is the Co-Founder and Managing Editor of the Journal of Service Oriented Computing and Applications. **Palade** was Editor-in-Chief for the International Journal of Hybrid Intelligent Systems from 2010-2012 and is currently an Associate Editor for the Knowledge and Information Systems Journal. **Petrovic** is a member of the editorial board for the International Journal of Systems Science, **de Freitas**, the IEEE Transactions on Learning Technologies, **Chao,** the International Journal of Web Information Systems and **James**, the International Journal of Data Theory and Applications. Members of the Unit have also served as guest editors on 22 journal special issues during the census period.

Examples of Conference Organisation and Leadership: Most researchers serve on the programme committees for relevant conferences and regularly review papers. Some serve on international steering committees or chair international conferences. The Unit has held 16 conference steering committee memberships over the census period and 34 organising committee memberships. For example**, Chao** and **James** are members of the steering committee of the IEEE International Conference on Computer Supported Cooperative Work in Design. **Chao** served as Co-Chair of the IEEE conference on Enterprise Computing and E-Commerce in 2010 and the IEEE International Conference on E-Business Engineering 2013. **de Freitas** founded and chairs the steering group of the IEEE International Conference in Games and Virtual Worlds for Serious Applications (VS-Games). **Petrovic** was Program Co-Chair of 53rd Operational Research Conference held in 2011. **Palade** was Co-Chair of the ICMLA (International Conference on Machine Learning and Applications) in 2009 and 2010.

Examples of Keynote Speeches: Chao gave a keynote speech at IEEE Conference on Computer Supported Cooperative work in Design (CSCWD 2013), **James** gave a keynote speech at the International Conference on E-Business Engineering (ICEBE, 2012) and **de Freitas** gave a keynote speech at the 7th Norwegian Advanced Distributed Learning (ADL 2012) Conference. **Palade** gave a keynote speech at the 23rd IEEE International Symposium on Computer-Based Medical Systems (IEEE CBMS 2010) and at the 7th International Joint Conference in Computer Science and Software Engineering (JCSSE 2010).

Examples of Collaboration with Industry and Commerce: Chao and **James** have worked with Hildebrand Ltd, London to develop an innovative product for domestic energy usage monitoring (see **case study 11.2**). **Petridis**, **Dunwell** and **Hendrix** have worked with companies such as PlayGen (UK), I-maginary (Italy), Succubus Interactive (France) and Serious Games Interactive (Denmark) to run controlled trials in serious games for testing and evaluating the efficacy in a range of projects (see **case study 11.1**). **Petrovic** has collaborated with Severn Trent Water in developing a new forecasting method based on a modification of an evolving fuzzy system and has also collaborated with the Defence Science and Technology Laboratory of the MoD. She has carried out research on unmanned logistics vehicles, new methodologies for representing complex dynamic systems and fuzzy evolving systems for supply chain. **Iqbal, James** and **Doctor** work with Jaguar Land Rover on user aspects of on-board predictive systems. Our industrial and commercial collaborators have chiefly affected the research through posing problems that needed solving through research and subsequently working with the researchers, providing equipment and access to the working environment as well as providing some funding. Members of the Unit also take an active interest in their subject and professional community and in total hold 20 professional body memberships (for instance **James,** the British Computer Society, **Petrovic**, the Operational Research Society, **Iqbal**, the Higher Education Academy, and **Wang**, the IEEE and IET).

Examples of Collaboration with Academic Partners: The Unit currently has 14 active EU projects which involve collaboration. In addition to these, **Chao** collaborates with the National Chiao-Tung University (NCTU), Taiwan where the focus of the research is to develop new methods in service discovery and selection, based on quality of service. **Chao** also carries out research with Fudan University, China in the research and development of service-oriented software engineering for E-Business, specialising in data views and summarisation. **Anane** carries out research with the University of Birmingham on research projects and co-authoring of papers, particularly in the area of collaborative software. **Dunwell**, **Hendrix**, **Petridis** and **de Freitas** collaborate with SGI affiliates in South Africa, USA, Singapore and Mexico (mentioned previously – see sections c.i. and d.i.). They also collaborate with Graz University (Austria) on research seeking to understand processes of learning on a neuro-biological and neuro-physical level. Another important SG collaboration is with Skövde University (Sweden) which involves co-authoring papers and conducting staff exchanges.

Examples of External Examining Activity: Researchers from the Unit contribute to the wider community by acting as examiners for PhD students at other universities in the UK, EU or worldwide. During the census period 19 external examinations have been carried out: 14 in UK; four overseas; and one in European Union. Examples of the external establishments include University of Cardiff, University of Bradford, Delft University, and Anna University, Chennai, India.