Institution: University of Portsmouth

Unit of Assessment: 11 Computer Science and Informatics

a. Overview

This submission comprises 13 FTE Category A and 1 Category C staff. Computer Science and Informatics research is interdisciplinary, spanning 3 schools: School of Computing (SoC), School of Creative Technologies (SCT) and School of Engineering (SoE), with Computing being the lead organisational school. Research activities are concentrated around research groups reflecting common research interests with membership overlapping to engender collaboration amongst their members.

There are three broad research themes in this submission: Computational Intelligence, Networking and Security, and Health Informatics. (1) Research in **Computational Intelligence** is long established, with applications in the core areas of robotics, computer vision, machine learning, neural networks, evolutionary optimisation, and fuzzy systems; (2) Research in **Networking and Security** emerged from restructuring of activities and research groups reported at the last RAE 2008 with particular focus on the design, development and analysis of efficient and resilient inter-connected systems such as Clouds and virtualised environments; (3) Research related to **Health Informatics** has a predominantly computing perspective with important contributions to the modelling of patient care and standardisation of patient data.

b. Research strategy

Our research in Computer Science and Informatics recognises the strategic ambitions of the University in addressing fundamental and strategically important questions to deliver economic, social and cultural impact at regional, national and international levels. Following on from RAE 2008, we organised our research into three main thematic areas with the following strategic objectives:

- Strengthen and sustain research excellence in **Computational Intelligence**: from the broad area of Artificial Intelligence (AI) identified in the 2008 submission, we have focussed on the main fields of computational intelligence (evolutionary computation, neural networks and machine learning, and fuzzy logic). This concentration led to tangible results, both in terms of fundamental and theoretical research (as evidenced by the research outputs) and also in the development of technology oriented applications, leading to prototypes in robotics, motion analysis, computer vision and 3D face modelling and recognition.
- Establish and align research in **Networking and Security** to address important national and international priorities: evolving from the 2008 Parallel and Distributed Systems group, current research is driven not only by the technical aspects of systems such as wireless devices, Grid, and Cloud environments, but also by the legal and social concerns associated with the implementation of these systems, such as security and digital forensics, power consumption, and interconnectivity.
- Focus research in **Health Informatics** on applied research with maximum impact and benefit to society: this objective provided a clear direction to our Centre for Healthcare Modelling and Informatics in its effort to analyse large-scale data sources to inform and influence health policies and practices through data modelling.

Significant efforts have been made to bring together the scope of research activities and engagement with business and industry in order to sustain growth in research funding and deliver excellence in the quality of research. Indicators of achievement include increases in:

- the number of quality, peer-reviewed journal outputs returned in this submission.
- the value of external research income of 30% over the REF period.
- successful applications to a wider range of funding bodies.
- the number of registered Post Graduate Research Students (PGRS), with 31 doctorates awarded in the period, and 60+ current registrations.
- staff expertise in PGRS supervision.

The success of our strategy to support research that combines excellence with engagement with stakeholders can be gauged from the list of typical projects listed in section d.

The strategic plan also involved recruitment of new staff, especially early career researchers

(ECRs), aligned with the UoA's priority research themes. Our successful recruitment strategy is reflected in the fact that 9 out of the 13 Category A staff returned in this UoA were appointed after 2008 and the high percentage of ECRs in this submission (42%, compared with 8% in RAE2008). Resources have been focused on support for research sabbaticals, PhD bursaries and PDRAs in strategically important areas. These initiatives have provided direct support to researchers (**Cocea**, **Wang**, and **Gegov**), and allocation of a dedicated PDRA in a growing research field (**Aziz**: 18 months PDRA in Cloud Security policy).

While continuing the strong support for our established research areas in computational intelligence, priority fields have been also identified for further development such as Robotics and Computer Vision, Wireless networks and security. New interdisciplinary collaborations have been developed nationally and internationally, as evidenced by the increase in the number of joint projects and joint research outputs, and these have been consolidated through research exchanges, short-term secondments and a visiting lecturers programme. In recognition of the excellence within the Computational Intelligence research, a Leverhulme Visiting Fellowship supported the secondment of a postdoctoral researcher from Yanshan University, China, bringing research expertise to complement that within the University and underpinning an on-going international collaboration.

In *Computational Intelligence*, research is broad-based focusing on the design and implementation of systems that exhibit intelligent behaviour using a variety of sensor networks, methods, and data. Robotics and Computer Vision research comprises Approximate Computing, multi-sensor based information fusion, analytics and their practical applications, especially in cognition-driven biomechatronics, and pattern and face recognition and classification (**Liu**, **Ju**, **Yu**, **Ait-Boudaoud, Chiverton**, **Jordanov**). Research in Machine Learning (ML), Self-Organised systems, Optimisation and Neural Networks in particular, explore the hybrid meta-heuristic methods for global optimisation, based on Low-Discrepancy Sequences, Genetic Algorithms and Simplex search techniques (**Jordanov**, **Ait-Boudaoud**, **Cocea, Wang, Frei**). The development of computational intelligence methods with applications in modelling complex systems based on the newly pioneered research field of rule-based networks (**Gegov**).

Networking and Security research falls into two interrelated areas: (i) security and digital forensics and (ii) mobile and wireless technology. We concentrate on the process of engineering secure distributed systems such as Grid and Cloud computing (**Aziz, Liu**), and more specifically on the applications of formal analysis techniques to the verification of security properties and modelling of systems in a secure manner (specification of security properties at an early stage of the software development process). We investigate through simulation the performance of networks for multithreaded architectures that include simulation of wireless networks to address performance of new protocols and quality of services for harsh environments (**Adda**). We engage in research on fusing information from novel sensing technologies, and we will concentrate on the advancement and development of algorithms that can fuse data from cameras, radars, lidars, bracelets, and unattended ground sensors, to yield a set of tracks that can identify anomalous behaviour (**Adda**, **Aziz, Ju**).

In *Health Informatics,* our collaborations with other academic institutions in the UK, US and Europe, health sector organisations (particularly Portsmouth Hospitals NHS Trust), and companies have enabled the development of research outcomes that were deployed in the health sector. We expanded our work on clinical outcome modelling to encompass further data sources, models specific to clinical conditions, and more sophisticated analysis techniques (**Prytherch**). We continue to facilitate the adoption of our models by the NHS and other organisations. In the area of telecare, we continue to seek large-scale data sources that provide us with raw data that we can use to model patterns of daily living.

Strategic aims: our overarching strategic objectives for the period 2014-2020 are to further develop and enhance research strengths aligned with our research priorities. We will increase our standing and visibility within the thematic areas through a combination of high impact publications, significant collaborative research projects and enhanced engagement with user communities. Specifically we will:

1. Increase our collaborative and interdisciplinary funding applications to sources that address key national and international strategic priorities, such as the RCUK Global Uncertainties, Digital Economy and Lifelong Health and Wellbeing programmes, relevant topics within the EC Horizon 2020 Societal Challenges and Industrial Technologies programmes and TSB competitions to support innovation.
2. Establish a cross-institutional network in Computational Intelligence to build on the strengths of our research and consolidate work undertaken jointly with the Department of Mathematics, the Business School, and others.
3. Maintain and extend our focus on deploying technologies to solve industry-related problems to complement our interest in addressing fundamental and theoretical research.
4. Continue to increase our PGRS recruitment through a combination of institution-funded scholarships, international fee paying students and industry-sponsored studentships.
5. Support staff to establish and maintain internal and external collaborations, including those of an interdisciplinary nature. “Pump-priming” funds will be provided for engagement with users and participation in the formation of research grant consortia.
6. Increase research leadership through the strategic appointment of senior researchers in the thematic area of Networking and Security, and through researcher development opportunities and training across the UoA.

c. People, including:

i. Staffing strategy and staff development

Our staffing policy to build research strength has been based on the principle that the majority of new academic staff appointments must demonstrate a profile of research of international standing relevant to our thematic areas. Our strategy has focussed on the appointment of early career researchers and the development of research leadership through effective mentoring and coaching. Succession planning and staff development ensure that retirement, recruitment and retention of staff are properly and efficiently managed to provide continuity, vitality and stability.

Staff development within the UoA is fostered through an engaging research environment, a culture of support and formal schemes that include effective inductions, mentoring and performance development and review. Researchers are encouraged to engage with development programmes provided by the University. A mentoring system has been developed, where experienced academics are “paired” with new members of staff in assisting the latter in their research career development. Members of staff are supported to apply for external research funding through grant-writing workshops, peer review, and individual guidance on grant writing. The University of Portsmouth is working towards full adoption of the Concordat to Support the Career Development of Researchers, and adheres to best practice in the conduct and monitoring of recruitment and promotion practices at all levels. All staff have an annual performance development review, including discussion of longer-term research development needs and aspirations.

Early career researchers are supported in developing their research internationally through PhD studentships and post-doctoral support in line with strategic investments. They are also provided with guidance and workshops to prepare first grant applications and they are offered excellent support to engage with industrial partners. Conduct of high quality research and demonstration of research leadership has been recognised through promotion that is externally peer-reviewed. **Liu** and **Gegov** were promoted to Professor and Reader in 2011 and 2009 respectively and a number of ECRs were fast-tracked to senior lecturers (**Aziz** (2012), and **Cocea** (2013)). We are fully committed to the goals of equality and diversity; the University is a holder of an HR Excellence in Research award from the European Commission and is committed to actively promoting the role of women along with other groups traditionally under-represented in science and engineering. The University joined the Athena SWAN charter in 2011 and a strategy is in place for the University to achieve Athena SWAN Bronze by 2014, with individual departments within the Faculty of Technology applying for Silver awards in the 2015-2017 window. Since 2008, women academic appointments in the School of Computing for example, have increased from two to seven, representing a sizable shift in what is considered a traditionally male-dominated area.

To deliver our strategic objectives, our future staffing strategy will build on the current practice to recruit academic staff with international research profiles, encourage existing staff to raise their career aspirations and ambitions to lead research, and make additional senior key research appointments to support the development of our early career researchers. Through the University internal funding, we will underpin and strengthen areas of excellent research by extending the range and scope of international collaborations and joint initiatives with industry. This will include the provision and funding of a programme of staff exchange and collaboration with international institutions, as well as business and industry.

ii. Research students

Research students are a vital component of our research environment and the UoA has significantly increased its PGRS cohort (60+ currently registered students). There have been 31 completions during the REF period. We achieved this through targeted PGRS recruitment, our MSc postgraduate students, and efficient use of external, self-funding and university bursaries. In addition, university collaborative agreements for PhD awards with international partners have also contributed to the research student environment. We have adopted a more holistic approach to the PhD studies – expecting as output the creation of an innovative, autonomous, interdisciplinary researcher of international standards, and not just someone completing and defending a PhD thesis. To achieve this, we implemented the following practices:

Supervision. All PGRSs have supervisory meetings at least once per week and each meeting is electronically documented (brief notes on progress and agreed objectives). The full supervisory team (usually three supervisors) meets the student at least once per semester. For tracking the meetings, monitoring progress, and identifying the PGRS's development needs, the Graduate School (GS) has invested in the SkillsForge software, which can be used for monitoring all PhD students in the Faculty. The Postgraduate Team supports the research students and their supervisors with regard to admission, progression and examination arrangements. There is also an annual workshop "Best Practice in Supervising Research Students" run by the GS aiming to help staff with limited supervisory experience.

Development programme. The GS provides induction and training sessions for new students and key elements of generic research and transferable career development skills for all PGRSs, as well as running PGR workshops on PhD thesis writing, vivas training etc., as outlined by Vitae and the RCUK. The PGRSs are required to take relevant modules of the Graduate School Development Programme including, for example, *Essential Research Methods* and *Statistics for Engineers*.

Major review and Annual Appraisal. A Major Review at the end of the first year is carried out for all research students to approve their candidacy for PhD studies. In order to pass it, they have to submit a written report and go through a mini-viva with three assessors. All students also have annual appraisals with their full supervisory team.

Research culture. We run a fortnightly research seminar, featuring internal and external speakers covering topical research issues of interest. The PGRSs are expected to deliver at least one annual presentation through a programme of research seminars and are, in addition, encouraged to present at national and international conferences, workshops and other research events. Prior to their thesis submission, students are encouraged to publish papers in refereed journals and conferences. Annual prizes are awarded to the best PhD poster, oral and journal papers at the Faculty's annual Research Day. The students are also strongly advised and supported in applying for research internships as part of their research projects – recent examples include EPSRC KTN Industrial Mathematics (IM) Internship with BP and current IM sKTP grant with AIRBUS Operations Ltd.

d. Income, infrastructure and facilities

Income

We have generated approximately £930K of research income (eligible for REF inclusion), which represents a 30% growth on the level reported in 2008. This income has derived from a variety of sources including Research Councils, EU, UK Industry and Consultancy. Interactions between the members of staff and the University Research and Innovation Service have been very effective in

responding to calls from governmental and industrial bodies alike. Examples of successfully funded projects include:

EPSRC, value: £284K, "Exploring Human Hand Capabilities into Multifingered Robot Manipulation": this project led to the development of a portable 16-channel EMG system that integrates pressure, position and haptic sensors. It provides a unified platform for analyzing hand motion that has been used to capture standard datasets for hand gestures with related algorithms development.
KTP in partnership with KG&S Ltd, value £217K, "Monitoring System for the Elderly Living in Residential Dwellings": the objective of the work was to design and integrate a hardware and software platform to collect and aggregate data from a range of sensors to monitor and ensure the wellbeing of patients. The ultimate aim of the partnership was to embed into the company the product development and support capability to take the system to market.
Leverhulme Trust visiting Fellowship, value: £72K, "Investigation of human movement analysis via brain signals": this project enabled Professor Liu's team to work with Dr Ouyang Gaoxiang from Yanshan University, China; a collaboration that subsequently led to an award for Dr Ouyang from the National Science Foundation of China, and several joint papers.
KTP in partnership with Smart-e Ltd, value: £117K, "Audio-Visual Distribution System Over Computer Networks": the objective of the project was to engineer novel intelligent audio-visual switching products for network-efficient adaptive digital media streaming over existing computer networks. The project builds on the outcomes from two previous partnerships and aims to develop capability in the company to produce digital audio/video switching products to maintain the company's market position.
Royal Society, value: £12K, "Cue Fusion for Human Motion Analysis": This is a two year international travel grant which provided the opportunity for a project collaboration between Professor Liu's team and Professor Kubota, one of the leading scientists in computational intelligence from Tokyo Metropolitan University, Japan. This project led to the EPSRC grant, on which Professor Kubota was one of the international partners.
Consultancy with ESROE Ltd, value £34K, "Generic Radar Identification – Neural Network Classification": the overall aim of the project was to identify and implement a methodology for generic radar identification that provides valuable and stable information contributing to situation awareness for the military user (DSTL/CDE) with particular focus on the evaluation and validation of intelligent solutions based on Neural Networks.

We have also attracted funding for staff secondment with international organisations and these exchanges were supported directly by the host institution and/or in country funded (e.g. "Smart Healthcare System for Elderly (£6K) – British Council (Italy)", "Efficient Resonant Modes Estimation for Power Grids – Visiting fellowship provided by the University of South Wales (3K) – Australia"). Newly appointed staff have also remained actively engaged on external grants they had worked on before joining the School: EU FP6 "GridTrust"(**Aziz**) and "XtreemOS IP" (**Aziz**), EU FP7 "Consequence" and "BASYLIS" (**Ju**). These activities contributed to our capacity building and enabled continued engagement with international collaborators.

Infrastructure and Facilities

In 2012, a strategic investment was made to create integrated Computing research and teaching facilities (infrastructure: ~£500K and equipment: ~£120K). A newly refurbished suite of laboratories which includes a digital forensics lab, a pervasive computing lab, a usability lab, and a mobile computing lab together with dedicated research spaces for PGR and PGT students have improved the research environment for students and staff. The creation of this dedicated space provides opportunities for researchers to engage in cross-thematic projects and it enables better interactions amongst PGR students and with PGT students. The success of this investment is evident in the increase of PGR recruitment in 2013, which has seen a three fold increase in 2 years (5 new PhDs in 2011 to 15 new PhDs in 2013). This new environment is also enabling effective support for early career staff to forge closer relationship with more experienced researchers.

All staff and researchers are provided with modern computing resources supported by a resilient University network infrastructure. In addition to providing departmental computing facilities and

licenses for specialist software (e.g. MATLAB and others), our researchers use dedicated client software to access SCIAMA, a 1000+ cores distributed-memory High-Performance Computing cluster, managed by the Institute for Cosmology and Gravitation. (SCIAMA provides over 2TB of memory, 85TB of fast parallel storage, and 10TB of NFS storage, supported by 3 interconnection networks: 100bT, Gigabit, and Infiniband). A dedicated supercomputing technician supports these activities.

e. Collaboration and contribution to the discipline or research base

New interdisciplinary collaborations have been developed nationally and internationally, as evidenced from the joint projects, collaborations and joint research outputs. Arrangements have been made to accommodate external visitors by providing offices and computing facilities. Notable international collaborations include:

- ***Liu*** with Prof. Zhu from Shanghai Jiao Tong University, China, and Prof. Kubota, Tokyo Metropolitan University, Japan, are developing further research in computer vision and human motion analysis through a grant from the Royal Society on the project "Cue Fusion for Human Motion Analysis". He has also investigated prosthetic manipulation in robotics with Prof. Mellish, Bristol Robotics Lab, as part of the EPSRC project "Exploring Human Hand Capabilities into Multifingered Robot Manipulation".
- ***Jordanov*** has collaborated with Dr. Licciardi and Prof. Novakov from GIPSA Lab, University of Grenoble, France, on investigation of Nonlinear Principal Component Analysis for pre-processing of data sets. He was awarded a Royal Academy of Engineering "Distinguished Visiting Fellowship" to host Prof. Kasabov, from Auckland University of Technology, New Zealand and promote research collaboration in the computational intelligence field.
- ***Adda*** and Prof. Bouridane from Northumbria University are investigating network security and cyber crime; and with Prof. Niar, University of Valenciennes, France, on embedded system and mobile computing. His joint research activities also include collaboration on wireless networks, MANETS and network routing clustering with scientists from Bulgarian Academy of Science.
- ***Wang*** is collaborating with the National CIMS Engineering Research Centre at Tsinghua University, China, on development of methods and computing platforms for distributed and collaborative simulation for complex systems. His has also collaborated with Key Laboratory of E&M, Zhejiang University of Technology on advanced decision-making methods and conflict resolution in complex design problems.
- ***Aziz*** is working with Prof. Arenas, IE University, Spain and Prof. Wilson, STFC, Rutherford Appleton Laboratory, Oxford, on network security and digital forensic project as a co-investigator of EU FP7 *STREP Contrail* project.
- ***Yu*** is involved with interdisciplinary project in neuroscience and psychology (Dr. Miller, ECIT; Prof. Schyns, Glasgow University; Dr. Cristobal, Max Planck Institute of Biological Cybernetics, Germany; and Prof. Sun, Beijing University of Technology, China), developing "Dynamic 3D emotional facial expression generation platform". The platform has been used worldwide since its development in 2011 (Princeton University - Social Cognition and Social Neuroscience Lab; Caltech, USA; University of Nijmegen, the Netherlands; Geneva University, Switzerland; and University of Montreal, Canada).

Knowledge transfer, collaboration and contribution to industry are an important part of our research activities. For example, ***Ju***'s work on the EU FP7 BASYLIS project (developing new security systems for rapid identification of potential threats in refugee camps) included a number of industrial partners. Liu has also collaborated with one of the world-leading prosthetic technologies company (*Touch Bionics Inc*.) investigating and designing a multiple-sensor capture system for human hand motion analysis. ***Jordanov*** has recently worked on the IMsKTP project with AIRBUS Operations Ltd. and on the EPSRC/KTN Industrial Mathematics project "Gap analysis and optimization of BP hydroprocessing prediction model" with BP. Special focus in our research effort is the collaboration with and the KT impact on local industry, especially SMEs from the Portsmouth area, e.g.: The Centre for Defence Enterprise/DSTL project with *ESROE Ltd*. (***Jordanov***); Consultancy vouchers with *New Leaf Law Ltd*. (***Aziz***), and the KTP with *Flight Data Services Ltd*. (***Adda***).

Our colleagues pursue active involvement with professional institutions and continue to collaborate and serve on editorial boards of top international journals, and organising leading conferences in the research areas of interest:

- ***Liu*** has served as General Co-Chair for the 2011 Int. Symposium on Fuzzy Robotics, France; and a Program Chair for the 2008/09/10/11 Int. Conf. on Intelligent Robotics. He is a Fellow of IET; Senior Member of IEEE; and a Fellow of the Japan Society for the Promotion for Science, 2008. He has also served as Applied Technology Committee Chair on the Robotics Task Force, the IEEE Comp. Intelligence Society 2009-2011; a proposal evaluator for Hong Kong Research Grant Council; EPSRC proposals' reviewer; Nature Science Fund of China; and the EU FP7. He is an Associate Editor of: IEEE Trans. on Industrial Informatics; IEEE Trans. on Systems, Man and Cybernetics; and several int. journals. He has also been invited Guest Editor of journal issues for several IEEE Trans. and other journals. Within the last four years, Liu has been invited to give conference plenary talks, tutorials, and seminars at several IEEE conferences, over 30 universities and 10 companies;
- ***Ait-Boudaoud*** is a Fellow of IET; member of the Engineering Professors' Council; convenor and chair of the 2013 EPC congress, and reviewer (Reader – Engineering and Computer Science Submissions) of the Queen's Anniversary Prizes for Higher and Further Education 2011 and 2013; he has also served as a reviewer of several International journals and conferences.
- ***Jordanov*** is an Associate Editor of several international journals: KB and Intelligent Eng. Systems; OC Intelligence; and KE&Soft Data Paradigms. He has served as a Guest editor of Neural Computing and Applications journal (international collaboration with Prof. Apolloni, University of Milano, Italy, and Prof. Kasabov, Auckland University of Technology, New Zealand) and has edited several Springer's research books. He has also served as Programme chair and co-editor of the Knowledge-Based and Intelligent Information & Engineering Systems (KES) 2010 (UK) conference proceedings;
- ***Aziz*** is an Associate Editor of the Int. J. of Security, and J. of Security and Comm. Networks and has taken part in the programme committees of several conferences.
- ***Ju*** has served as a Guest Editor of a special issue of Int. J. of Humanoid Robotics (collaboration with Prof. Palm, Orebro University, Sweden, and Prof. Borovac, University of Novi Sad, Serbia).
- ***Wang*** has also served as a Guest Editor of a special issue of Int. J. on Service Oriented Computing and Applications. He has been invited to give keynote talks at IEEE Computer and Management (CAMAN) 2012 and the Institution of Engineering and Technology International Conference on Design and Manufacture for Sustainable Development (ICDMSD) 2013 conferences and has been co-chair of ICDMSD 2013 and session chair of 2012 and International Conference on e-Business Engineering (ICEBE) 2013.
- ***Gegov*** has presented 4 plenary lectures (2 at IEEE conferences) and 8 conference tutorials (4 at IEEE conferences). He has had 8 reviews published on 2 research monographs authored by him (2 in IEEE journals). He has been a book review editor for an Elsevier Journal, associate editor for an IOS Press journal as well as assessor for EPSRC and ARC. He has been programme committee member for 8 conferences (4 IEEE conferences) and member of 4 international scientific organisations.
- ***Prytherch*** has been a member of the Audit and Research Committee of the Vascular Society of Great Britain and Ireland; referee for the British Journal of Surgery and European Journal of Vascular and Endovascular Surgery. He was part of the Portsmouth Hospitals Team that won Patient Safety Awards 2010 (HSJ and Nursing Times) in the "Technology and IT to improve Patient Safety" category. He was also part of the Portsmouth Hospitals Team led by Gary Smith that won the Bupa Foundation Patient Safety Award 2010.