Institution: Oxford Brookes University

Unit of Assessment: UoA 11 Computer Science and Informatics

a. Overview

Research in UoA 11 includes activities within the Department of Computing and Communication Technologies, and also collaborative applied research between this Department and other areas of the university including Health and Life Sciences, Engineering and Built Environment. There is also a high level of engagement with external academic and research partners, and with industry. The Department of Computing and Communication Technologies is one of six departments within the Faculty of Technology, Design and Environment. The Faculty has a high level of both disciplinary and interdisciplinary activity and has a deeply embedded commitment to supporting high quality research.

The research environment is supported by a central research office overseen by an Associate Dean with two research managers, a grants specialist and a PGR administrator. Each department also has a research lead who, with the Head of Department, co-ordinates research activities, and a research tutor responsible for PGR activities. Further specialist support is provided by the University Research and Business Development Office in areas such as contracts, bidding, commercialisation, KTPs and EU projects.

Within the Department of Computing and Communication Technologies research is structured into two centres: Intelligent Systems Engineering (ISERC) and Dependable Systems Engineering (DSERC). Each research centre has a Director: Prof. **Harrison** for DSERC and Dr **Crook** for ISERC. Prof. **Harrison** is also the Department's Research Lead. Dr **Crook** is Head of Department.

Each centre comprises a number of groups that are responsible for day-to-day managements of research activity and which inform the overall research vision.

DSERC is organised into the following three research groups:

Applied Formal Methods (AFM): **Zhu, Bayley, Younas** and **Ou**.

Advanced Reliable Computer Systems (ARCOS): **Jabir** and **Sengul**

Applied Software Engineering (ASE): **Harrison, Bayley** and **Younas**

ISERC is organised into the following three research groups:

Artificial Intelligence and Vision Group (AIV): **Cuzzolin, , Hartley, Cheng** and **Sturgess**

Cognitive Robotics Group (CR): **, Cuzzolin** and **Steil**

Communications, Media and Electronic Technologies (COMET): **Ball**, **Sengul** and **Ou** [Dr Ball is not returned in this UoA].

b. Research strategy

Future Vision and Strategic Plans

The future research vision for the UoA is to meet the challenges posed by the increasingly complex needs of the future global community through the provision of *intelligent* and *dependable* systems. The two components of this vision will be realised through two research centres: Intelligent Systems Engineering (ISERC) and Dependable Systems Engineering (DSERC) within the following research themes: Intelligent Interaction (T1), Reliable Systems (T2), and Smart Networking (T3). The themes will be supported by aligned investment in both staff and facilities in the two centres, and will be the basis of a high quality platform of integrated research. These

centres bring together a range of research groups and sub-disciplines and provide an environment conducive to the development of integrated holistic research. Within the centres there is a high level of collaboration and pooling of expertise and facilities, and teams with specialist skills can be configured to address opportunities and research agenda.

As well as operating independently, the centres will integrate with other University disciplines (replicating the current successful models of collaboration), with external academic and research communities, and with industry where there is a long track record of success. This is all in the context of an overall vision for the UoA to become an inclusive learning and research community where there is a strong synergy between teaching and research and where teacher, researcher and learner are equally valued.

The strategic themes are addressed by one or more research groups in the two research centres:

Cognitive Robotics Group (CR) undertakes research into machine intelligence and cognition (T1). This group consists of three academics, one post-doc and research students. The group is primarily addressing ways in which interactions between robots and humans can be made more natural.

Artificial Intelligence and Vision Group (AIV) carries out research in the areas of machine learning, artificial intelligence, neural networks, uncertainty theory and computer vision (T1). This group consists of three academics, two Early Career Researchers, two Postdocs and research students. The work of the group focuses on how computationally tractable, theoretically sound and biologically inspired mechanisms facilitate intelligent interaction between humans and machines.

Applied Software Engineering (ASE) undertakes research into tools techniques, methods and models for software development and maintenance (T1, T2). This group consists of three academics, one Postdoc and research students and is concerned with whether mechanisms devised in AI can be applied to the challenges of automatically developing reliable software systems.

Advanced Reliable Computer Systems (ARCOS) carries out research into the design, testing, and verification of reliable computer systems (T2). This group consists of two academics and three contracted R&D engineers. The groups research focuses on how the theoretical limitations of design automation, error and attack tolerance can be formally identified and mitigated in real systems.

Applied Formal Methods (AFM) is concerned with the theoretical foundations of software engineering, from formal specification and modelling to design and testing (T2, T3). This group comprises four academics and research students. The research area concerns how formal methods can be applied to assess the reliability of software solutions and benefit the production of reliable service oriented distributed systems.

Communications, Media and Electronic Technologies (COMET) investigates cross-disciplinary research across user-centric intelligent networks and their applications (T1, T3). This group consists of three academics and reseearch students. The research is aimed at determining the type of intelligent communications, media and electronic technologies that need to be developed and how these can they be integrated to facilitate green and smart societies.

The Department has recently created two new specialist research laboratories, one for each research centre, equipped to provide the necessary infrastructure to address these research areas. The strategic objectives that have been adopted are to:

1. Continue to develop intellectual capital by selective strategic appointments.
2. Strengthen the project portfolio around three research themes by seeking external funding and building collaborations with partners that complement current expertise in the UoA.
3. Implement the future impact strategy outlined in REF3a.

Current Position with Respect to RAE 2008

At the time of the RAE 2008 submission, research in the UoA was structured into 4 groups: Computer Vision, Natural Computation, Web Technologies and Applied Formal Methods. The focus of research interests has however evolved since 2008, resulting in the current group structure previously described. This includes the expansion of Computer Vision to AI and Vision (AIV) and the growth of the software engineering area. Research Centres have also been formed as a primary unit of research management, all within the context of a major reorganisation of the management structures of the university from Schools to a smaller number of Faculties.

Since RAE 2008 there have been significant staff changes, some very recent. For RAE 2008, 11 category A staff were returned (10.67 FTE). Of these three are returned in this submission together with eight new appointments, one transferee to the UoA from a different UoA and one newly research active member of staff. Prof. Torr has very recently been appointed to a new Chair at the University of Oxford, Prof. Clocksin and Dr Curtis have left the university, Dr Zajicek has retired, and Prof. Duce's activity has focussed on knowledge exchange in this period.

Significant new strategic recruitment has taken place. Prof.**Harrison** was recruited as Reader in 2010 and awarded a chair in 2011. Dr **Crook** took a career break through an RA post in Prof. Pulman's group at Oxford and subsequently returned to take the position of Head of Department and leader of ISERC in 2011. Dr **Jabir**, previously returned under General Engineering, has been promoted to Reader (2009) in this period. Dr **Cuzzolin** was recruited as an Early Career Researcher, was subsequently promoted to Reader and has recently been given leadership of the AIV group. He was successful in obtaining internal and EPSRC first grant funding, and has been given increase levels of responsibility. Dr **Sengul** and Dr. **Ou** have been recruited as research-active senior lecturers in communication systems. Dr **Sengul** has recently been appointed as Postgraduate Tutor for the Department of Computing and Communication Technologies.

The future strategy stated in RAE 2008 posed a range of challenges for different groups. For Computer Vision the challenge was to sustain its high level of external funding and achievement. Successes included Prof. Torr's receipt of a Royal Society Wolfson Merit Award (2008), a successful bid (subject to contract) for an ERC Advanced Researcher (£2m now transferred to Oxford), and a total of £1.3m funding awarded for EPSRC and KTP projects. All four of Prof. Torr's KTPs have been awarded Grade A, Outstanding quality in the independent assessment process, putting them in the top five per cent of KTP projects nationwide. One of these also won the award for the best KTP in the UK (2009). Over this period the Computer Vision group also won four best paper awards at major conferences.

The Natural Computation group was diminished when both Dr **Crook** and Dr olde Scheper took career breaks, but Dr **Crook**'s work during this period has since led to the foundation of the new Cognitive Robotics Group and has contributed significantly to the future research vision for the UoA. Work on natural computation has been absorbed into the AIV group.

In the 2008 return the future strategy statement sought to "… better integrate the research interests of newer members of staff" into the Applied Formal Methods Group. This has been achieved, for example, with **Zhu** and **Bayley** forming a very fruitful collaboration in the area of formal aspects of design patterns. This partnership has resulted in a COMPSAC best paper award (2008).

The Web Technologies group intended "to increase participation in knowledge transfer partnerships and to increase the work in the digital forensics area". Prof. Duce turned his attention to the knowledge transfer partnerships area. During the period two KTPs have been successfully completed: Nominet (graded outstanding) and WildKnowledge Ltd (with the Faculty of Health and Life Sciences), whilst a third with Oxford-based Global Water Intelligence (jointly with the Business School) has just started. Work on digital forensics was pursued through the KTP project with Nominet and also resulted in an initiative to explore potential links between design patterns, security and digital forensics. This resulted in two successful workshops on Cyberpatterns organised by **Bayley**, Duce and **Zhu** (2011, 2012).

c. People:

Staffing Strategy and Staff Development

The staffing strategy since RAE 2008 has followed a 'recruit and develop' pattern, linked to the previously described research themes: Intelligent Interaction, Reliable Systems, and Smart Networking. The UoA has invested in senior appointments (**Harrison**, initially appointed Reader), four early career researchers, together with five postdoctoral fellows and associated PhD students to support their research. The appointment of **Harrison** introduced an empirical software engineering thread to complement the formal methods activity, the aim being to build up a strong software engineering activity to complement the strength of the computer vision group. Mentoring from senior staff in the UoA has supported early career staff. **Cuzzolin**, for example, was initially appointed to a fixed-term lectureship, subsequently to a permanent post and latterly promoted to Reader. He has become an established researcher, having obtained first grant EPSRC funding, produced a flow of publications some of which have been prize-winning, and has now settled into the processes of seeking research funding and managing a research group. The Faculty recognised **Cuzzolin** as a 'most promising researcher' and rewarded him with a fully-funded PhD student and increased research time under its 'Next 10' research accelerator programme. **Bayley**, appointed in the last RAE period has developed his research through a very successful collaboration with **Zhu**.

Staff have been developed and promoted through the period, including a new professorship (**Harrison**) and three new readerships (Ball, **Cuzzolin** and **Jabir**). Two of the three new senior lecturers that were appointed during the period are returned in this UoA (**Ou** and **Sengul**). Two former RAs (Sturgess and **Cheng**) have been promoted to early career researcher posts to pursue independent research.

Torr moved to the University of Oxford in October 2013. During the period he was supported and successfully obtained a Royal Society Wolfson Merit Award toward the start of the period, and, subject to contract, an ERC Advanced Grant at the end of the period.

Two strategic international appointments at Professorial level have been made (**Steil** and **Hartley**). **Steil** is assisting the UoA with the establishment of the new Cognitive Robotics Group and the associated laboratory. With Torr's departure, leadership of the computer vision work has passed to **Cuzzolin** who is now leading the AIV Group. In line with the research strategy, it is expected that the work in computer vision will take on a more applied stance within cognitive robotics. The appointment of **Hartley** has been made to strengthen the applied aspects of the research. Torr will also continue to collaborate with the UoA in this work.

The career development of researchers is monitored by the Research Lead and the Faculty Research and Knowledge Exchange Committee (RKEC) in accordance with the Concordat to Support the Career Development of Researchers. During the period, a number of students and researchers on fixed-term contracts have secured career-enhancing positions at the end of their contracts. For example, Dr. Kohli is a senior researcher at Microsoft Research Cambridge, Dr. Kumar has been appointed as an Assistant Professor at Ecole Centrale Paris and INRIA-Saclay, Dr. Ek is a Senior Researcher at KTH Stockholm, Dr. Alahari is a researcher at INRIA-Grenoble, Dr Sagar took up a position in commerce in Canada.

Oxford Brookes conforms to the Athena Swan charter for women in science, and recognises and celebrates good employment practice for women working in STEM subjects in higher education and research. The university received the Bronze Award in recognition of this in 2013. The UoA actively maintains a healthy gender balance in staffing and research appointments. Female research students are supported in participating in BCSWomen events. Dr **Sengul** is a contributing editor of ACMW Europe. Equal Opportunities and Diversity Co-ordinators advise and support staff on equality and diversity issues.

Research Students

The Directors of the Research Centres plan and agree the distribution of internal resources for funding PGR positions. Vacancies are advertised through each centres networks of contacts as well as through university, national and international channels. Applications are then processed by the PGR Tutor. Appointments are made following interviews with the appropriate Research Centre Director, the PGR Tutor and other relevant staff. Appointed students are supervised by a team of at least two supervisors who receive dedicated time from their workload plan for supervision.

The University's Graduate Office deals with all the central administration for the enrolment, registration, and transfer of students from MPhil to PhD. It also organises training seminars on key transferable skills such as preparing for the viva. There are also a number of social events held throughout the year. There are many opportunities for students to engage with the faculty through weekly seminars, conferences, and symposia and students are encouraged and expected to attend these sessions. Each year the Faculty holds a conference for students from across the Faculty to present and discuss their work. This provides an excellent opportunity to present preliminary ideas and findings and get feedback from staff and students. It also helps build the skills necessary for presentations at more formal academic conferences. There is also an opportunity for students to prepare posters of their research and display these. Prizes are given to the best presentations and posters.

Procedures for registering and monitoring students have been put in place at different levels of the University. These procedures are designed to ensure that there are members of academic staff, with clearly-defined roles (e.g. PGR Tutor), to whom the researcher can turn for advice. These procedures also assist and monitor the students in setting and achieving realistic deadlines for the milestones in the progress of their research. For example, the University provides a personal development planner and diary to all students which they should complete alongside their training programme. The planner enables them to agree with their supervisor and PGT any training and career development needs they may have and how these can be met. The diary is intended to be filled in at various times e.g. at the start of their course and towards the end of each year to enable them and their tutors to plan future activities. Student progress is monitored via annual reports, a review of the student's training record, and an interview with the student held by the PGR Tutor and a senior academic. Progression is subject to satisfactory performance and the approval of the University Research Degrees Committee.

d. Income, infrastructure and facilities

During the period a variety of strategic investments have been made in developing infrastructure and facilities. The Faculty has recently invested £88k in an HP cluster to support data intensive processing needs of ISERC, DSERC and other UoAs within the Faculty. The Faculty has also invested in autonomous vehicle resources for the interdisciplinary Intelligent Transport Systems (ITS) project. This combines mechanical and electrical engineering with communication technology, computer vision and software engineering.

At the UoA level, an investment of more than £100k is being made to build and equip two new research laboratories due for completion in October 2013. These will provide physical space and facilities for our two Research Centres, DSERC and ISERC, the latter with state-of-the-art robotic technology. This includes the purchase of a RoboThespian humanoid robot that will support research into human-robot interaction and the role that robotics can play in teaching and learning. During the period a special motion-capture laboratory was also created which was fully equipped through a substantial donation from an industrial collaborator (Vicon). These laboratories will enable academic staff, PDRAs and PGR students to be co-located to help create the desired inclusive learning and research community that will maximise synergy and interaction. The new laboratories will provide an environment that will support the vision of creating robust, intelligent artefacts that begin to address the complex needs of the global community.

In line with the objectives, all research active staff are supported in their applications for external

funding in a variety of ways. Over the period funding was successfully obtained from a variety of sources including EPSRC, EU, KTP and CASE awards. As described, the UoA has been successful over the period in engaging with industry through KTP partnerships, achieving national recognition. The new research centres are actively sharing expertise in grant writing and have created a shared research agenda which will enable staff to be better placed to proactively search for essential resources.

The UoA also engages in a variety of forms of consultancy, including short courses for industry (e.g. Scientific Computing course delivered for research staff at Culham Laboratory), hiring of staff, facilities and equipment (e.g. film director – John Twycross), CPD courses for primary and secondary school teachers as part of the Computing at Schools agenda, and QA for the certification of assessment procedures for Enterprise Architects by the Open Group.

e. Collaboration and contribution to the discipline or research base

Exemplars of collaborations and contributions to the discipline

Each of the research centres engages in a wide variety of collaborations both formal and informal across all three research themes. Collaborations within the Intelligent Interaction theme, for example, include joint work with industrial partners such as Sony, OMG (AIV group), which have resulted in contributions to new products and have also fed back fresh research challenges to the theme. This activity has been supported by KTP and EPSRC CASE awards. At a less formal level, discussions have taken place with Engineered Arts, a leading robotics company in the UK, which have resulted in the procurement of RoboThespian and plans for more formal collaboration in the future (CR group). The AIV group has an extensive network of international collaboration evidenced by their joint publications. Contributions to the discipline include the creation of new algorithms, techniques and software for AI and computer vision problems (e.g. Torr's work on Conditional Random Fields and skin segmentation).

Collaborations within the Reliable Systems theme include joint work with national and international research institutions (e.g. Newcastle University, Bristol University, Bengal Engineering University of Calcutta, University of Massachusetts Amherst) resulting in joint publications and patent applications. The ARCoS group has three patents that are going through commercial exploitation, e.g. with the MoD DSTL Future digital systems. One patent has been approved by EPO, and will be granted. Funding sources for this include Finance South East, CommercialISE, HEIF4/5 funding. The ASE Group has links with Spain and the USA. Links with **Harrison**'s former PhD student Rodriguez (now at University of Alcala, Madrid) have resulted in joint publications. PhD students and staff from Alcala visit frequently and have contributed to projects with outputs in the field of design for testability (including built-in-self-testability architectures to provide enhanced assurance for safety and security against side channel attacks, **Jabir**). Contributions have been made to building synergies between AI and SE, and developing automated SE techniques (e.g. refactoring for time-lapse evolution). Formal methods have been applied successfully to the precise description of design patterns, their composition, and formal semantics for meta models.

In the Smart Networking theme the EU funded Network of Excellence MONICA, coordinated by Oxford Brookes University, is a good example of collaboration with research groups in Europe and China. The COMET group also has collaborations with the University of Essex, Deutsche Telecom Labs (Germany), TU-Berlin, CreateNet (Italy), Gwangju Institute of Science and Technology (Korea) that led to joint publications. Contributions to the discipline have been made to the design of reliable development-operations wireless network architectures and quality of service provisioning in wireless mesh networks.

Exemplars of Interdisciplinary Research

The Faculty supports and encourages interdisciplinary research both informally by bringing together colleagues from a wide range of disciplines and formally through the Faculty RKEC. In UoA 11 interdisciplinary research is being pursued by all the Research Groups. For example the

AIV Group collaborates with the Faculty of Health and Life Sciences on the application of novel gesture recognition techniques to health monitoring. A joint interdisciplinary collaboration with Oxford's Lukasiewicz on the semantic web with action recognition is progressing to Leverhulme and Google Research applications. A NERC project on imprecise probabilities for impact assessment is in preparation with researchers in the Department of Planning. The CR group is collaborating with the School of Arts and the Department of Psychology on the development of biomimetic robotic devices. The AIV group, the CR group and the COMET group have collaborated with the Department of Mechanical Engineering and Mathematical Sciences through the University's Intelligent Transport Systems doctoral training programme.

The AFM group has coordinated a university-wide multidisciplinary research project on 'Safety Technology' funded internally from 2008 to 2010. It involved researchers across the university with expertise from computer science, electronic engineering, media and telecommunications, mechanical engineering, and psychology.

Exemplars of Leadership

Crook	Reviewer and Evaluator, EU Framework programmes Guest Editor BioSystems Workshop Chair IPCAT 2008
Cuzzolin	Editorial Board of IEEE SMC-C (now IEEE Trans. Human-Machine Systems) Editorial Board of IEEE Trans. Fuzzy Systems PC Chair BELIEF 2014
Duce	Eurographics: elected Honorary Fellow 2013, chairman 2007/8, secretary 2009- Elected Fellow of the BCS 2012- Editorial Board BCS FACS Member EPSRC Peer Review College
Harrison	Editor-in-Chief Software Quality Journal, published by Springer Editorial Board IET Software PC Co-Chair ESEM 2012, RAISE 2012, RAISE 2013. Member EPSRC Peer Review College
Jabir	Invited guest speaker, VentureFest, Oxfordshire, 2011
Ou	PC Chair ChinaCom 2010: Information and Coding Theory Symposium.
Sengul	PC Co-chair WinMee 2012
Younas	PC Chair AINA 2009, ANT 2010-12, MobiWIS 2011, FTRA 2012, ATP 2012, WAMIS 08-2010 Keynote: EIDWT 2012, INCoS 2012, Editorial board: Int. Journal of Service Oriented Computing and Applications, Int. Journal of Information Science and Computer Application, Guest editor: Journal of Service Oriented Computing and Applications, Int. of World Wide Web: Internet and Web Information Systems, Journal of Ambient Intelligence and Humanized Computing, Journal of Systems and Software, Int. Journal of Computer and System Sciences
Zhu	Member EPSRC Peer Review College Editorial Board: STVR, SQJ, MAGS, Int. Trans. on Systems Science and Applications, Int. Journal of Big Data Intelligence. PC Co-Chair, IEEE/ACM AST 2006-SOSE 2011, 2013 General Co-Chair, MobileCloud 2014. Visiting Professor at the National University of Defence Technology (NUDT), China.