Institution: Teesside University

Unit of Assessment: UoA 11

a. Overview

This submission is organised into a single grouping of 13 members of staff who, together with the PhD students and the research assistants they supervise, constitute the membership of the Digital Futures Institute (DFI). The main research topics are Artificial Intelligence (Planning, Autonomous Agents); Interactive Systems (3D graphics, web based); Programming Research (program verification, algorithmic theory). Sustained collaboration across topics and towards various application areas is the rationale for a flexible organisation instead of distinct research units.

b. Research strategy

Our RAE 2008 strategy comprised several primary objectives: i) consolidate at least one research topic into European standing, ii) explore new research topics, iii) improve the selectivity and completion rates of PhD students, iv) quantitatively develop research through Early Career Researchers (ECR), already employed and newly appointed, and the recruitment of new staff.

These objectives were realised as follows:
i) Autonomous Agents research has featured regularly in first-tier conferences, has received several international awards (see below).
ii) New research topics have been developed, mainly medical document analysis (3 outputs in this submission) and affective computing (4 outputs).
iii) PhD completions for the period are 29.8 FTE, compared to 7 FTE in RAE 2008 (see section c. below).
iv) 7 new members of staff have been appointed who are research active; the current submission includes 38% ECR.

There has also been an evolution in the research philosophy, to address the previous divide between applied research in interactive systems and more fundamental research represented by formal methods and programming research. Considering that interactive systems research was strongly underpinned by AI technologies, we have strengthened the fundamental AI component, in particular in terms of Planning technologies, through the appointment of two staff in Planning (Porteous, Gregory) and one in Multi-Agents Systems (Zeng). This has significantly improved the standing of research in Autonomous Agents, both theoretical and applied, which has increased its research output and obtained a number of awards (see below).
In addition, we have also established connections between these two areas, one example being the use of Linear Logic to formalise narratives (represented by Bosser's submitted outputs).

The diversity of approaches nevertheless intersects in well-defined scientific communities, in particular the Autonomous Agents community, as evidenced by the importance of the Autonomous Agents and Multi-Agents Systems (AAMAS) conference and the eponymous Journal, as publication venues for our submitted output. This contributes to the group's sense of identity, by submitting to, and attending, the same conferences.
The majority of publications in this submission can be categorised as Artificial Intelligence (ACM classification [22]), other represented fields being User Interaction, and Fundamental Computer Science (algorithmic theory, programming research, game theory).

Our publication strategy has been adapted to encourage publication in high-impact, selective venues, using the CORE classification as an indicator, rather than imposing an in-house list of conferences and journals. As a result, there has been a significant increase in CORE A*/A conference publications, such as: AAMAS, the International Conference on Automated Planning and Scheduling (ICAPS), the International Joint Conference on Artificial Intelligence (IJCAI), the AAAI Conference on Artificial Intelligence (AAAI), ACM Multimedia, ACM Virtual Reality Software and Technology (VRST), ACM Intelligent User Interfaces (IUI), ACM Principles Of Programming Languages (POPL), Computer Aided Verification (CAV), IEEE Transactions on Software Engineering, International Journal of Human-Computer Studies. It should be noted that this aligned

naturally with publication objectives in each area, and the need to appear in the most specialised venues (for instance ICAPS for Planning and Scheduling and AAMAS for Autonomous Agents). As a consequence of the successful adoption of this strategy, 90% of our publications are now CORE A/A* versus 50% for our RAE 2008 submission. Following common practice in computer science, the submission includes a balance of selective conferences and journals.

Our funding strategy is adapted to the various research themes and recognises that certain topics may only be appropriate to specific funding sources. The objectives of the funding strategy are to sustain main themes, to promote collaboration (including with industry or user bodies), and to explore new topics. Staff have applied to a range of funding mechanisms: EC FP7, EPSRC responsive, EPSRC proactive, Technology Strategy Board. A specific effort has taken place to secure high-quality FP7 funding, in particular through the Future and Emerging Technologies (FET) Programme, which has resulted in two FET Projects being awarded: CEEDS (FP7-ICT-258749) and MUSE (FP7-ICT-296703).

Both EPSRC and FP7 schemes now allow Category A staff (including PIs) to be charged to their grants; however, we have made limited use of this option in order to privilege the appointment of Research Assistants and Research Fellows.

QR funding received for the period has been entirely allocated to research activities and in our case has been subdivided into four budget lines which have operated throughout:

- a staffing budget has funded three permanent, full-time academic appointments
- a research student budget line has been specifically dedicated to completion bursaries (see below, Research students)
- to retain Research Assistants, a specific bridging fund to extend their contract until new external funding becomes available
- a travel and equipment line: this guarantees that travel to major conferences is covered even for outputs produced outside of externally funded projects, or after project completion; and that specialised equipment can be purchased or upgraded

c. People, including:

i. Staffing strategy and staff development

13 staff (12.7 FTE) have been included in the current submission, compared to 7 staff in 2008.

Since RAE 2008, two members of staff have retired, and one (ECR at the time) has left the University to take a Lectureship in Europe.
Eight of the staff returned have been appointed since 2008, as part of our recruitment strategy, throughout the reporting period (2010: Qin, Porteous - 2011: Ferreira, Gilroy - 2012: Zeng, Ventre, Gregory - 2013: Read); appointments have been made at Senior Lecturer level (5) and Reader level (2). It should be noted that two of these seven staff (Gilroy, Porteous) were initially appointed as Research Fellows (at post-doctoral level or higher) on EC-funded projects, thus establishing a career path for research staff. Of these eight posts, only three were initially QR-funded (but on permanent contracts[1]), the others being generic vacancies.

In addition, a number of Research Assistants (post-graduate) and Research Fellows (post-doctoral) have been employed, principally on EC-funded projects, but also on internal funding derived from QR, for an average of 5-6 FTE annually, throughout the reporting period. Five of these have been made permanent, either as academic staff (at Senior Lecturer level) or as permanent Research Fellows positions (in particular attached to the Institute).

Two members of staff who were ECR during the RAE 2008 assessment period but were not submitted then, are now part of our submission as established researchers (Bosser, Truran). Of the 13 staff now returned, 5 are classified as ECR (38%), although it should be noted that the

[1] Only in one case (Zeng) we have academic staff currently on a fixed-term contract (ending 30/06/2015), due to visa restrictions.

number of outputs submitted often exceeds the minimum threshold determined by their appointment date. The current submission also includes two women (Bosser, Porteous) and is a better reflection of gender balance in the Unit than in RAE 2008, when it failed to include any.

Staff at L/SL level are offered the opportunity to collaborate with existing research activities to facilitate their integration, for instance by being associated with relevant externally funded projects. They are also offered mentoring by a senior academic as part of their initial development plan.

Staff at Reader level and above are encouraged to acquire external funding and develop their own activity. For recent appointments (over the census period), University support has been provided in the form of fully-funded PhD scholarships. This practice has recently been extended to more junior staff who have demonstrated high potential, for instance through their publication output.
Research training, for instance in Research Ethics, is available via the University's Graduate Research School (GRS), which also coordinates PhD supervision training. Other forms of training include participation in information days on funding schemes (nationally and at European level). Finally, training is provided in the use of specific software and hardware: one recent example being a one-week on-site session dedicated to the Unity3D game engine (which has been used as part of two FP7 projects).

We have updated previous procedures for workload management that determine for each staff the balance between research, teaching and other activities, while retaining our commitment to investment in research. Our objective has been to improve transparency and encourage high-quality output.
Research allowances, defined as the fraction of time devoted to research only[2], are determined annually on the basis of the publication output of the previous year. On average, to achieve a research allowance > 55%, any member of staff would require 0.7 CORE A* publications per year (calculated *pro rata* for multi-authored papers).

For newly appointed staff, output from the two previous years is taken into account. As an outcome of this policy, most of the staff returned to the current exercise have benefitted from research allowances > 40% since their appointment, and throughout the reporting period. Further allowances, which can be combined with the above, include PhD supervision allowances, and any effort charged to externally funded projects under Full Economic Costing (FEC).

Additional dispositions prevent the policy from becoming excessively formulaic. These include:

- Mitigating the CORE classification in case of national conferences (to the exception of large US national conferences); this has since been updated in the 2013 amendments to the CORE classification
- graceful degradation of research allowances with the preservation of a half-allowance from the previous year, not to discourage risk taking
- the possibility to allocate a 20% allowance to ECR on the basis of preliminary work (e.g. short papers at first-tier conferences)
- the possibility to spread allowances over two years when exceeding thresholds and targets in any given year
- taking into account individual and mitigating circumstances accepted by the University

ii. Research students

In the period since 2008, a number of changes were made to significant aspects of research student procedures and support, both centrally and for our Unit of Assessment. Applications for admission were improved in order to link applicants more closely with areas of research strength and the most appropriate supervisors within these areas, based on evidence such as publications and existing grants. We have maintained the concept of a supervision team of up to three supervisors, while reinforcing the visibility of supervision through the introduction of compulsory log books. A new Post-Graduate Tutor was appointed for Computer Science, to liaise with GRS and lead on the implementation of new procedures. He also sits on the Research Development

[2] In addition to contractual research and scholarly allowances, and PhD supervision allowances.

Committee of the School of Computing.
The first year of new doctoral programmes was the object of regulatory changes, which enforced mandatory research training aimed at improving timely and successful completions. Formal progression review at the end of the first year was introduced to ensure that a student's first year work was progressing adequately at doctoral level. Formal progression now includes a formal Board meeting and each subsequent annual review involves a presentation of work to a Panel, allowing students to gain experience of oral defence of their work and to receive critical feedback from assessors, both of which have improved student completions. Several initiatives have taken place to promote cohort identity, such as Teesside University Research Network, which organises monthly meetings and presentations. All students are provided with information about research-specific support at training events and in a range of guidance documents.

We have also revisited funding modalities for our PhD students. A first measure was the introduction of completion bursaries for students whose progress was deemed sufficient to envision completion within the next six months: six students (20% of completions) have benefitted from such a bursary. The University has also introduced fully funded PhD bursaries (including full time fees), five of which have been attributed to our Unit of Assessment over the reporting period. Finally, some Research Assistants on externally funded projects (FP6, DTI), have been registered as part-time PhD students, provided their research topic was fully aligned with the project's activity. They have also received support in terms of registration fees through various mechanisms.

The number of PhD completions has increased substantially from 7 FTE in our RAE 2008 submission to 29.8 FTE. Even taking into account the new reporting rules for completions in REF 2014, a more selective recruitment policy, as well as the new supporting measures, had a significant impact on the number of completions, as well as average completion time. More specifically, since these new measures have been introduced, the average completion time has been reduced from over 6 years to 4 years for full-time students and now stands at under 7 years for part-time students.

d. Income, infrastructure and facilities

We have received research income from various sources: EPSRC (standard scheme; Digital Research in the Wild), DTI, EC FP6, and EC FP7. In terms of EU funding, we have participated in all types of instruments: STREP, Integrated Projects (IP) and Networks of Excellence (NoE), with 5 active projects between 2008 and 2013 (the total value of these projects for Teesside exceeds 2.5M€, however spanning slightly beyond the current reporting period). One development since RAE 2008 has been the acquisition of high-quality EU funding, in particular through participation in two FET projects: one Proactive FET Integrated Project (CEEDS) and one FET Open STREP (MUSE) - the latter call being particularly competitive. The total value of research expenditure has increased significantly since RAE 2008 (by almost 200%, and by over 50% per FTE). In terms of project management responsibilities, Cavazza has been co-ordinator of the FP7 IRIS Network of Excellence (2.4M€ total funding, FP7-ICT-231824) and acting coordinator for the last two years of the FP6 COMPANIONS Integrated Project (10M€ total funding, FP6-IST-034434).

Our research infrastructure comprises dedicated office space, computer facilities, as well as specialised equipment required by some activities (such as user interaction and affective computing).

The Phoenix building hosts research activities, providing consistent space for academic staff, RAs and PhD students and supporting constant interaction. The layout is one of open spaces with separate single offices for academic staff, with an average 15 sqm per person. The building includes a large range of meeting spaces, from break-out areas within the open space, to 10-seats meeting rooms and boardrooms with large-screen projection facilities.
In several instances, staff have been involved in the design of the floor plan, and the building has flexible opening hours. The space also includes provision for demonstrations and user experiments.

There is extensive provision of computer equipment through various sources: School budget for academic staff, a specific equipment budget line derived from QR funding (see above), as well as

through externally funded projects. As a result of these combined funding sources, staff benefit from individual high-end computers (with specific 3D graphics or video capabilities) and personal laptops, which are frequently renewed. Further common laptops are available for demonstration purposes.

The School has been operating a CAVE™-like immersive projection system since 2006, which has been constantly upgraded during the reporting period. In 2009, the projection system evolved from low-cost DepthQ 3D projectors to high-end Christie Digital Mirage S+6K at a cost of over £100k. In 2011, the CAVE's computer system ORAD 8x PC cluster was replaced by a high-end 4x PC cluster with professional GPUs. Two outputs for the current submission have been based on user experiments carried out in this new configuration, as well as the development of our CaveUDK middleware.

The School also has extensive facilities for Motion Capture and 3D prototyping which are shared between teaching and research activities. These include One Animazoo 'Gypsy' Exo-skeleton system, an ipiSoft markerless motion capture system, OptiTrack facial Motion Capture System and Brekel Face Motion Capture, Minolta 'VI-700' Laser Scanner, a ZCorporation 'Z Printer 450' 3D Printer, and a CubeX Duo 3D printer.

In addition, research in affective computing has access to a full range of devices for physiological signals acquisition, including three ProComp™ Infinity devices with their accessories and a BrainAmp 8-channel EEG signal recorder.

e. Collaboration and contribution to the discipline or research base

Collaborative research takes various shapes, from individual contacts (through former supervision, previous affiliations) to more formal involvement in joint projects. During the reporting period (FP6, FP7), we have been in contact with over 40 institutions through collaborative projects, and have developed a sustained collaboration with a subset of them, in particular: University of Augsburg (FP6 CALLAS, FP7 IRIS, FP7 CEEDS), University of Helsinki (FP6 CALLAS, FP7 CEEDS), University of Brescia (FP7 IRIS).

Collaboration has involved the following institutions and topics over the period:
University of Augsburg (Germany): affective computing, multimodal interfaces
University of Brescia (Italy): multimedia technologies, video processing
University of Helsinki (Finland): multimodal interfaces
University of Minho (Portugal): Mathematics for the Information Society
CLARTE (France): Virtual Reality middleware
Goldsmiths College (UK): Virtual Reality usability, entertainment psychology
Ecole Normale Superieure (ENS) de Paris (France): subliminal perception in 3D interfaces
University Complutense of Madrid (Spain): interactive narrative, intelligent 3D interfaces
Functional Brain Centre of Tel Aviv Medical Centre (Israel): Brain-Computer Interfaces
Conservatoire National des Arts et Metiers (France): interactive theorem proving
University of Salerno (Italy): Autonomous Agents and Multi-Agent Systems

National Institute of Informatics (NII, Japan): discourse analysis, intelligent 3D interfaces
Royal Melbourne Institute of Technology (RMIT, Australia): Interactive Narrative
University of South Australia (Australia): Information Retrieval
National University of Singapore (Singapore): Program Verification
Nanyang Technological University (Singapore): Social Networks Analysis
University of Georgia (USA): Multi-agent Planning
University of Auckland (New Zealand): British Academy-funded project on 'The cultural validation of online psychometric scales'

Collaboration also manifested itself via several staff exchanges:
Cavazza held the British Hispanic Chair at University Complutense of Madrid for 2011-2012 and was an invited researcher at RMIT (2011) and NII (multiple stays between 2008 and 2013).
Qin visited National University of Singapore for 3 months (late July- Mid Oct 2010)

Truran visited the University of South Australia (UniSA) for a total of 4.5 months (funded by various grants from UniSA)
As a result, 80% of outputs returned with a Teesside main affiliation[3] have at least one external co-author and 58% have at least one international co-author.

We have also collaborated with various industrial partners in the course of our research (this refers to joint research or research on industry-defined challenges, rather than knowledge transfer or exploitation):
With Eidos Interactive plc / Square Enix – follows from a previous Technology Programme project. This has resulted in one of very few publications co-authored by a game company (in the IEEE Transactions on Computational Intelligence and AI in Games);
With Epic Games Inc., the developers of the Unreal™ game engine, to develop CaveUDK, a virtual reality middleware based on the game engine (offering source code access and developers' network support under a specific non-disclosure agreement);
With Telefonica I+D in Madrid, on the integration of the main demonstrator for the FP6 COMPANIONS project (this has led to various joint publications and public demonstrations, including the AAMAS 2010 Best Demonstration award and an appearance on Euronews as part of the ICT 2010 coverage);
With Electrolux Ltd, on the design of intelligent 3D interfaces for consumer products (as part of the FP7 CEEDS Project).

Over the reporting period, we have also presented 10 software demonstrations at high-impact conferences: AAMAS (2008; 2009; 2010; 2011; 2013), ACM Multimedia (2010; 2011), ICAPS (2011; 2013), ACM IUI (2012), often in conjunction with paper presentations.

Staff returned have received a number of international awards during the reporting period, which distinguish current or previous publications, as well as software demonstrations or participation in software challenges:

- ICAPS 2013 Influential paper award (Porteous + 2 externals)
- ICAPS 2013 Best application award (Porteous, Charles, Cavazza)
- AAMAS 2013 Best Paper award (Ventre + 2 externals)
- AAMAS 2010 Best Demonstration award (Cavazza + externals)
- Euro iTV 2011 Grand Challenge 2nd prize (Porteous, Charles, Cavazza + externals)
- ICAPS 2012 runner-up for Best Paper award (Gregory + externals)

It should be noted that we have received these awards for the two most relevant and most represented conference venues in this submission (AAMAS: 8 outputs submitted; ICAPS 4 outputs submitted).

Conference Organisation and senior PC roles (Chair): IEEE Theoretical Aspects of Software Engineering (TASE) 2009 PC Co-Chair (Qin), ACM Intelligent User Interfaces (IUI) 2010 PC Co-Chair (Cavazza), ACM Multimedia 2010 PC Co-Chair (Cavazza), Unified Theories of Programming 2010 PC Chair (Qin), International Conference on Formal Engineering Methods (ICFEM) 2011 PC Co-Chair (Qin), Foundations of Digital Games (FDG) 2011 General Chair (Cavazza), INTERACT 2011 Short Papers Chair (Cavazza), Symposium on Abstraction, Reformulation, and Approximation (SARA) 2013 PC Chair (Gregory), ACM CHI 2013 Area Chair (Van Schaik), ACM Multimedia 2013 Arts Chair (Cavazza), International Conference on Automated Planning and Scheduling (ICAPS) 2013 Publicity Chair (Porteous).

Membership of Programme Committees for first-tier conferences include: ACM Multimedia 2011, 2012 (Cavazza); ICAPS 2012, 2013 (Porteous, Gregory); AAMAS 2009 (Cavazza), 2010 (Cavazza, Zeng), 2011 (Cavazza), 2012 (Cavazza, Zeng), 2013 (Cavazza, Zeng); IJCAI 2011 (Gregory, Cavazza, Zeng); IJCAI 2013 (Zeng).

The total Programme Committee membership by staff returned for the reporting period exceeds

[3] This excludes outputs produced by staff prior to joining Teesside.

150 instances, including: ACM Intelligent User Interfaces, ACM Virtual Reality Software and Technology, ACM Conference on Electronic Commerce, ACM International Conference on Multimodal Interaction, International Symposium on Formal Methods (FM), ACM SIGPLAN/SIGBED Conference on Languages, Compilers, Tools and Theory for Embedded Systems (LCTES), International Conference on Web Intelligence (WI)/Intelligent Agent Technology (IAT), IEEE International Conference on Healthcare Informatics, Advances in Computer Entertainment Technology.

Van Schaik is associate editor of the *International Journal of Human-Computer Studies, Interacting with Computers* and *Behaviour and Information Technology*; Gregory is associate editor of *AI Communications*, Cavazza is associate editor of *Entertainment Computing* and editorial board member of *Virtual Reality*.

Invited talks: AAAI 2013 spotlight track (Ventre), IEEE Computational Intelligence in Games 2010 (Cavazza), Computer Entertainment Supplier's Association Developers Conference (CEDEC, Japan) 2010 (Cavazza), Taiwan AI Forum 2011 (Zeng), ACM VRST 2008 Panel on Semantic Modelling (Cavazza).
Tutorials: Porteous was an invited speaker at the 2011 Advanced Course on Artificial Intelligence (ACAI-11), which was co-located with the International Conference on Automated Planning and Scheduling (ICAPS 2011). Ventre was an invited speaker at the 2012 Summer School on Algorithmic Game Theory in Samos Island (Greece).

Staff have been regularly solicited by funding agencies nationally and internationally for the evaluation of research proposals and research projects:

- ONR (Switzerland); Charles, Cavazza
- Medical Research Council; Van Schaik
- EPSRC; Qin
- NSERC (Canada); Qin
- EC FP7 (several ongoing projects, and Calls for Proposals n. 1, 3, 5, 7); Cavazza
- VQR / Anvur (Italian research assessment exercise); Cavazza
- Portuguese Foundation for Science and Technology (FCT); Cavazza
- Agence Nationale pour la Recherche (France); Van Schaik, Cavazza
- Deutsche Forschungsgemeinschaft (DFG, Germany); Van Schaik, Cavazza
- Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO, Netherlands); Van Schaik

Our research activities also include significant inter-disciplinary aspects, although our submitted outputs focus mainly on the Informatics aspects, and are published in Computer Science venues.
The main overlapping disciplines are:
Arts and Media, in particular Digital Arts. This has been a constant since FP5 and FP6 projects, and constitutes an application area for new modes of interaction, such as affective computing. This has resulted in several publications in multimodal interfaces and user experience. Cavazza was ACM Multimedia 2013 Arts Co-Chair (including the Arts Exhibition at the FAD Museum of Design in Barcelona).
Psychology: Represented by van Schaik's work on user experience and web aesthetics, as well as work on Entertainment Psychology with Goldsmiths College and the Free University of Amsterdam (as part of FP7 projects IRIS and CEEDS)
Medical Informatics is represented by work in medical document engineering as well as 3D visualisation of medical protocols, in partnership with the Haute Autorité de Santé, France. Three of our submitted outputs are based on this line of work, which also constitutes one of our impact case studies.
During the reporting period, we have developed interactions with *Neuroscience,* in the field of Brain-Computer Interfaces (with Tel Aviv's Functional Brain Centre); or subliminal interfaces as part of the FP7 FET CEEDS project (with ENS, France).