Institution: University of Essex

Unit of Assessment: 11 - Computer Science and Informatics

a. Overview

UoA11 at the University of Essex undertakes research across two broad **themes**: **Artificial Intelligence and Communications Systems**. This submission includes 34.6 FTEs and draws in staff from the School of Computer Science and Electronic Engineering (**CSEE**) and the Department of Mathematical Sciences (**DMS**). Across the two main themes, members of the UoA carry out research in the **areas** identified below with individual members straddling more than one areas:

(1) Artificial Intelligence (23.2 FTEs)
- *Intelligent and Adaptive Systems: Fasli, Hagras, Lucas, Phelps, Poli, Tsang, Zhang*
- *Human Language Understanding and Technology: Fox, Poesio*
- *Brain Computer Interfaces (BCIs): Cinel, Citi, Gan, Poli, Sepulveda*
- *Robotics and Embedded systems: Gan, Gu, Hu, McDonald-Maier*
- *Information and Data Analysis: Dai, Harrison, Higgins, Lausen, Perperoglou, O'Hara, Vernitski, Williams*

(2) Communications Systems (11.4 FTEs)
- *Optoelectronics and RF: Adams, Balkan, Henning, Hurtado, Mirshekar, Zakhleniuk*
- *Future Networks: Chorti, Thomos, Walker, Yang, Zheng*
- *Signal Processing Foundations: Newton, Sangwine*

Research within the UoA focuses on exploring fundamental questions in these areas, while applied research is undertaken to provide technological and engineering solutions, methods, algorithms and frameworks to pressing problems.

The UoA's thematic research is complemented by the **Research Centres** in **Computational Intelligence**, **Digital Lifestyles**, **Computational Finance and Economic Agents** – **CCFEA**, and the newly established **Centre for Assisted Living Technologies**. These Centres provide further foci of activity and have overlapping and cross-cutting membership, drawing in staff from across the UoA, the Science and Health Faculty and the University. They also support interdisciplinary research and collaboration and provide the means for engaging and working with user communities in order to promote research impact.

The research of the UoA is supported through **Research Laboratories** that provide the required infrastructure and testbeds to undertake internationally leading experimental research.

b. Research strategy

Essex has a long-standing tradition of research into Artificial Intelligence and Communications. It was one of the first UK universities to house a central research activity in Artificial Intelligence, in the Department of Computer Science (CS), while the Department of Electronic Systems Engineering (ESE) pioneered a systems approach to telecommunications.

The changing character and increasing pervasiveness of ICT – especially with the trend towards increasing diversity, complexity, interconnectivity and scale of applications – has led to new research challenges that go beyond traditional subject domains. Recognising these challenges and the opportunities that they presented, and anticipating longer-term trends, in 2007 the University brought together the necessary sets of complementary skills to address future systems level problems by merging the two long-established CS and ESE departments into CSEE. The RAE 2008 submission combined research from the newly formed department and DMS. The strategy developed for REF 2014 aimed for a single UoA submission that would embrace the breadth of research within both CSEE and DMS.

(a) Strategy, Objectives & Achievements 2008-2013

Our **strategy, outlined in RAE 2008**, aimed to coalesce activities across the areas originally covered in the CS and ESE departments and to build on complementarities and synergies within CSEE and DMS. Our **vision** was to undertake *fundamental* research informed by the priorities of application areas and *applied* research, well-supported by strong theory. These core aims have guided our research during the current census period, underpinned by **three strategic objectives**:

1. *To **consolidate** our position as an internationally-recognised centre for leading foundational

and applied research in key areas of strength;

2. *To **grow*** nascent areas of future internationally leading potential;

3. *To **align*** research to external priorities and in particular toward addressing key societal problems and challenges.

In pursuit of these objectives, the work within the UoA has undergone major transformation. The research activities were refocused, re-aligned and reinforced by a strong collaborative ethos (within the UoA and the University, and with external partners). Recognising the systems-level challenges facing ICT, and the ever-increasing need for smarter, flexible, interconnected user-centred systems and services, the UoA has placed cutting-edge research in Artificial Intelligence (both traditional and modern AI) and Communication Systems at the centre of its activity. This approach has aligned well with RCUK priorities and emerging major research themes and societal challenges.

Our **strategic objectives in the period since 2008** have been achieved. The detailed intellectual contributions we have made are summarised in the submitted outputs in REF2. Here we provide a brief illustration of how each of the three objectives above has been achieved.

1. Consolidation: Fundamental and ground-breaking work continued to be produced in our key areas of existing strength. The generic multi-objective optimization framework MOEA/D (Zhang) is considered one of the three major frameworks in the area of multi-objective evolutionary algorithms. Zhang was awarded the *IEEE Transactions in Evolutionary Computation* Outstanding Award in 2009 for this achievement. Hagras made fundamental theoretical and practical contributions in the fields of general type-2 fuzzy logic systems and fuzzy embedded agents. His work was recognised in an Outstanding Paper Award in *IEEE Transactions on Fuzzy Systems* – he is the only researcher in the field to have won this award twice (2006; 2013). Our pioneering work in advanced robotic systems (Hu, Gu) has been recognised in the recently published Witty review heat maps. Yang explored innovative Internet architectures that can meet the ever-increasing traffic and growing security demands, looking at the type of data transferred among users rather than its location. Acknowledged as an outstanding contribution to redefining the existing Internet design, Yang received an award from the *Future Internet Assembly* (FIA, 2013).

2. **Growth in significant new areas:** As part of a collaborative project with NASA JPL, Poli, Sepulveda and Cinel's work on BCIs has shown how multiple brains can be used to guide remote vehicles in space applications. Lucas researched novel Monte Carlo Tree Search algorithms that combine selective search with evolution and temporal-difference learning to improve performance over time and adapt to novel situations, with particular application in games technology (this resulted in his winning the BCS 2012 Machine Intelligence prize). Tsang's research in constraint satisfaction has been employed by BT for their national infrastructure / support systems, specifically for work scheduling and infrastructure design, as well as for job allocation and optimisation. Walker has pioneered novel high-speed connectors and electronics, enabling, for the first time, complete 10GbE backbone connectivity in railway trains. This ground-breaking solution has recently passed all the international compliance tests for use in the hostile railway environment.

3. **Alignment with external agendas and needs:** Research within the UoA has been strongly aligned with the strategic priorities of RCUK in the areas of Healthcare Technologies, Digital Economy, and Intelligent Infrastructures. An important strand of Hu's work has focused on developing intelligent wheelchairs, including a number of novel hands-free human-machine interfaces and autonomous navigation functions for improving the mobility of the elderly and disabled. The work of Fasli and Phelps has focused on automated mechanism design and developing learning and adaptive strategies for competitive environments. McDonald-Maier's work on computationally efficient vision processing algorithms is increasingly important to facilitate sophisticated onboard vision systems for mobile robots and intelligent infrastructures with constrained power resources.

The achievement of these strategic objectives has been underpinned by:

▪   **High quality outputs:** Staff have published in the internationally leading journals in their respective areas including: *IEEE Transactions on Systems Man and Cybernetics / Fuzzy Systems / Computers / Evolutionary Computation / Wireless Communications / Antennas and Propagation*; *Computational Linguistics*; *Brain and Language*; *ACM JASIST*; *Applied Soft Computing*; *Computational Statistics and Data Analysis*. Conferences include: *Autonomous Agents and Multi-agent systems* (AAMAS); *ACM SIGIR*; *IEEE Wireless Communications and*

Networks. In the five years since 2008, UoA members have published 726 journal papers, 1012 conference papers, 92 book chapters and co-edited 14 books and produced 12 patents.

- **Increased levels of external research funding** (see also section **d**): The UoA has been awarded 91 grants, worth £13.2M, i.e. £382k per FTE compared to a national average of £267k for UoA23 in RAE 2008.

(b) Strategy and Vision 2014 and Beyond

The UoA11 vision for 2014 and beyond builds on the foundations and successes of the 2008-13 strategy and aspires to develop into new and currently nascent areas. Our **core research goals** from 2014 forward are to:

- maintain our leading position in foundational and applied research in the fields of **Artificial Intelligence** and **Communications Systems**;
- expand and consolidate research in the thematic areas of **intelligent infrastructures** and **assisted living technologies** that cut across current research themes;
- increase the number of **high-quality research outputs**;
- increase the level of **external research income** per FTE in the next period;
- increase the **non-academic impact** of our work.

These goals will be achieved through the following **means and mechanisms**:

- **Monitoring and shaping the research** of the UoA through its Research Strategy Group (RSG) in order **to maintain alignment with external drivers and relevance to user communities' and societal needs**;
- Maintaining a **judicious staffing strategy** which ensures that people are replaced in ways that strengthen and develop our research community;
- **Managing staff loads** to ensure sufficient time-resource for conducting research and maintaining current research leave arrangements aligned closely to the research strategy;
- **Nurturing innovation** and strong support by senior academics and the RSG for individual researchers in framing and drafting proposals for external funding agencies;
- Continuing the pro-active approach adopted towards dissemination of funding opportunities and by invitation **brainstorming sessions** to incubate ideas and collaboration (see section **d**);
- **Supporting and mentoring early career staff** in their professional development through the assignment of a senior mentor and through the annual appraisal and review process;
- **Fostering cross-thematic, multi- and inter-disciplinary research and engagement with user communities** through our Research Centres;
- **Sustaining a vibrant multi-disciplinary research culture** encompassing research students through weekly thematic seminars, interdisciplinary seminars (see section **c.i** below) and regular engagement with companies through the Annual Joint Workshop with Industry.

c. People, including:

i. Staffing strategy and staff development

(a) Staffing strategy and its links to research strategy

Our staffing strategy rests on the **principle of self-renewal** guided by the needs and strategic direction of the UoA. We aim to appoint the best possible candidates globally to ensure the continuity of our research in areas of excellence and to expand the scope of our research. Since 2008, we have appointed 7 new full-time Lecturers and 1 Senior Lecturer. The appointments made during this period directly support the UoA's strategy for self-renewal in the theme of Communications (Chorti, Thomos and Zheng); expansion of activities in the areas of Assisted Living Technologies/BCIs (Citi), CCFEA (Phelps) and information and data analysis (Dai, Lausen and Perperoglu).

(b) Career development support and the implementation of the Concordat

Our policies aim to enable staff to maximise research potential, to reward and sustain high performance, but also to instil high staff morale. Career development support and advice is provided at all stages in research careers and the Head of School and Research Director are responsible for overseeing the implementation and compliance with the Concordat.

Annual appraisals held with all staff ensure continuous monitoring of performance and the prompt

identification of development needs. In addition to reviewing teaching and administration loads, these meetings consider the quality and volume of research outputs, research grant activity, knowledge transfer, and other achievements. In discussions with staff, quantifiable objectives for research, teaching and administration as well as further development for the coming year are set.

Probationary lecturers have reduced teaching and administration loads and are assigned senior mentors who provide individual guidance on career planning, research profile development and effective grant proposal writing. Essex has a three-year probation period and permanency criteria and performance expectations are made clear to all appointees and reinforced through the appraisals undertaken by the Head. In addition to an induction programme that all new staff must attend, the Learning and Development Unit (**LDU**) and the Research and Enterprise Office (**REO**) offer a wide range of courses, including on PhD supervision, teaching and learning approaches, leadership, and writing grant proposals.

Mentoring and career development arrangements also extend to **early career researchers** (ECRs) who are employed on research projects funded by EPSRC, the EU and other funding agencies. ECRs undergo an annual appraisal process to assist them in their career development. They take an active role in outlining their research and development objectives for the following year. The PIs on funded research projects and supervisors work with the Graduate School, REO and LDU to ensure **ongoing professional development** whilst advanced subject-specific scientific training is supported via participation in specialist external courses funded by the academic departments. ECRs are encouraged and supported to participate in all UoA activities, from contributing to seminars and workshops to networking. They are also given the opportunity to engage with limited teaching duties (e.g. occasional lectures/seminars to UG/PG students). Career support, mentoring and advice is also provided by **Emeritus Professors** (Brooker, Callaghan, Doran, Ghanbari, Hawksford, Lavington, Loudon FRS, Massara, Ridley FRS, Turner) who continue to play an active role and contribute to enriching the research environment of the UoA.

Great emphasis is placed on **continuous support and development** even after permanency and promotion have been granted. **Established UoA members** have many opportunities for training and development. LDU and REO offer a range of courses to staff, who are also supported in attending specialist external training courses and summer schools. The Research Strategy Group provides strong support in framing and drafting proposals for external research funding agencies. Academic and professional feedback also comes from presenting one's work at conferences and workshops and the attendance of staff at such events is supported through dedicated funds. Over a thousand papers have been presented to professional audiences over the last 5 years. **Generous research leave** (one term's paid sabbatical for every six terms' service) further supports UoA members in their continuing development. Whenever possible, we try to maximise the alignment between colleagues' research and their teaching as both benefit from this integration.

A set of seminars provides a forum for members of staff to present research ideas and findings while also bringing in leading external researchers and practitioners. The weekly **seminar series,** now in its 38th year of continuous existence, is aligned with the two main themes of our research (AI and Communications) and is open to all – staff, postgraduate and undergraduate students. The seminar series is complemented by the mathematics seminar series and **interdisciplinary seminars** in Theoretical Ecology and Complex systems (TECS), the Language, Logic and Computation (LLC) and interdisciplinary workshops such as the Annual Essex Statistics Workshop, the Annual Language and Computation Day and the Ageing and Assisted Living Workshop. An annual workshop is also organised with industry participation and contributions. The vitality of these seminars and events evidences the UoA's rich research culture.

(c)   International staff, visiting scholars and research fellowships

The UoA's vibrant research community also encompasses a very large number of **visiting scholars**. In the current census period, 60 visiting international scholars collaborated with members of the UoA while on visits that range from short stays to three years. The international collaborations and projects pursued during these visits are aligned with key areas of activity within the UoA and aim to support these as well as expand on nascent areas. The UoA has hosted several Fellowships (Hurtado: Marie Curie Fellow; Zakhleniuk: RCUK Academic Fellow; Nejabati: RCUK Academic Fellow).

(d) Equality and diversity

The University and UoA recognise the value of diversity and are committed to equality of opportunity. The University of Essex has a very clear policy supporting equality and diversity in relation to both staff and students. Specific objectives are set each year and an annual report is produced indicating achievements against objectives. The University facilitates flexible working, has a set of harassment advisers, and trains all staff involved in making appointments in equality and diversity issues. Essex is a member of the Stonewall's Diversity Champions programme, became a 'Two ticks' employer in 2008 and has just been awarded an Athena Swan Bronze Award. Within the UoA, staff come from diverse cultural backgrounds and from over 12 countries.

ii. Research students

The UoA has a thriving **research student community** and since 2008, 190 students have been admitted. Students are funded from a variety of sources. These include a substantial proportion holding competitive scholarships from EPSRC (including 6 industrial CASE awards); University postgraduate scholarships; overseas national government scholarships; and self-funding. The UoA has a strong submission rate and has awarded over 160 PhDs during this period.

PGR recruitment is overseen by the **Graduate Director for Research Students** and applications are handled by dedicated **Research Admissions Tutors** with responsibility for ensuring the quality and academic standards of the students recruited and the match between applicants' research interests and suitable supervisors. Research students need a good first degree (a 2 (i) or above) as a minimum in Computer Science, Electronic Engineering or related discipline, while a Masters level qualification in a related area is highly desirable.

Every student is provided with a desk space, and a state-of-the-art new personal computer whilst further specialist facilities and access to laboratories are provided based on the topic of research. Each research student has a named **individual supervisor** and a **Supervisory Board** consisting of two additional academic staff. Students meet regularly on a weekly basis with their supervisors. Progress is formally assessed four times a year: twice through **Quarterly Progress Review** meetings between student and supervisor and at least twice a year through a **Supervisory Board Meeting**. The **Research Students Progress and Monitoring Committee** is responsible for overseeing progress and reporting on all students to the **Graduate School (GS)**. All research students aiming for a PhD are now admitted as MPhil/PhD students and their PhD status cannot be confirmed until the first Supervisory Board in Year 2, though this decision may be postponed until the next Board that year.

The UoA and University **training provided for research students is extensive**. Prior to arrival, each student's training needs are assessed by their supervisor, and students are directed to relevant Masters modules and other courses they need to attend. Training needs are then reviewed at each Supervisory Board to check the training completed and what needs have emerged. The GS works with academic departments to set and monitor research student strategy and provide access to high-quality **cohort skills training and career coaching**. Training in discipline-specific skills is provided through advanced subject courses, while generic skills courses such as project management, effective communication and team working are offered through the University's **Proficio programme**. Students can also enrol to obtain teaching qualifications. All incoming doctoral students are given the equivalent of £1,000 each to spend on advanced training courses of their choice in consultation with supervisors. Research student culture and networking are encouraged in a number of ways: the GS runs regular events, including a Doctoral Welcome Conference and the annual GradSchool, while the UoA provides dedicated common rooms to facilitate and encourage student interaction. Students also have the opportunity to undertake limited teaching duties for their own career development (as graduate teaching assistants).

REO offers additional distinct services to research students, including a **postgraduate consultancy** service allowing students to gain or extend engagement with employers, a business incubation hub and advice on securing start-up funding and patents.

Research students are an integral part of the UoA's research culture and are treated as the colleagues and scholars we expect them to become. They are supported and mentored to become independent researchers and are funded to present their work at conferences through a dedicated research student fund. They are actively involved in the UoA's activities such as contributing to and

participating in seminars and workshops and, where appropriate, in scholarly activities such as reviewing for conferences and journals. Research students are actively encouraged and supported to engage with their peers within the UoA, but also in other universities. For example, the Flatlands workshop brings together research students working in the area of natural-language processing from the Universities of Cambridge, Essex, Oxford, and the Open University, and is run annually. A major success of the UoA has been the **Computer Science and Electronic Engineering Conference (CEEC)** which has been led and organised annually since 2009 by the research students with support from the School of CSEE. CEEC has grown from an internal event to a national one with the proceedings published by IEEE Computer Society Press, and it attracts increasing numbers of international submissions and presentations (in 2013, over 40% of the submitted papers were from non-UK based authors).

The UoA has recently been awarded EPSRC funding for a **Centre for Doctoral Training** (IGGI: *Intelligent Games and Game Intelligence*) which will fund 18 studentships at Essex over the next five years.

d. Income, infrastructure and facilities

(a)   Income

During 2008-2013 the UoA has been awarded 91 grants worth £13.2m from funding agencies, including the EU, EPSRC, Leverhulme, and the TSB. Members of the UoA have also collaborated in projects based at other host institutions funded by EC Framework Programmes 6 and 7 and by national research councils in the US. This is a substantial increase on RAE 2008 where, at the time of submission, the University of Essex's UoA24 income was £5.6m and UoA23 was £5.2m. In addition to funding obtained from RCUK and the EU, the UoA has been successful in securing research income from a variety of sources such as ERDF, TSB (11 KTPs awarded since 2008, a significant increase from the previous census period), as well as industrial companies such as BT.

(b)   Facilities

The UoA has a diverse set of **specialist laboratories** equipped with state-of-the-art equipment funded by strategic infrastructure investments, research grants and donations from industry. As research undertaken by the UoA11 requires extensive infrastructure support for new activities as well as continuous support and replenishment of existing equipment, the University's Research Strategy makes specific provisions (Strategic University Infrastructure Funds) for the renewal and development of infrastructure required to undertake research in the Sciences.

Facilities I: Artificial Intelligence

The **Robotics Laboratory** offers dedicated space for indoor robots. The University has invested over £1 million to equip the state-of-the-art laboratory with robotic systems, including 30 wheeled mobile robots, 8 flying robots, 3 robotic fish, 3 intelligent wheelchairs, 1 robotic arm and 1 robotic hand with 5 fingers. A VICON optic motion tracking system with 9 infrared cameras is fixed on the ceiling and provides reliable location information so that the performance of the developed robots and navigation algorithms can be accurately evaluated. The facilities have been deployed in research projects funded by the EU such a SHOAL (£461k), EPSRC, Royal Society, Royal Academy of Engineering, and a number of SMEs.

The **Brain Computer Interfaces Laboratory** is one of the best equipped for non-invasive BCI research in Europe, receiving more EPSRC funding than any other UK BCI lab as well as substantial support from other bodies. The Laboratory incudes 8 EEG systems (3 from Biosemi, 3 from gTec, one from Quasar, and one from Mindset); a near infra-red system; a Nexus EMG system; a Jazz eye tracker; a MagStim BitStim transcranial magnetic stimulator; many Biometrics Ltd electrogoniometers and accelerometers; two Edubot robotic manipulators; 3 Lego NXT robots; 3 VR systems; 4 Bionics motorised medical chairs; and a Viglen/Rocks cluster. This equipment has been used in funded projects, e.g. ESPRC RoBoSaS (£457k).

The **Intelligent Environments Laboratory** hosts the iSpace testbed for Intelligent Environments and pervasive computing and the iClassroom testbed for intelligent learning environments, established from a University investment of £240k, of which £120k was in the census period. These testbeds house indoor localisation systems, smart boards, immersive displays, various sensors, actuators and computing equipment used in our EU, EPSRC and industrially funded projects with BT, Intel and other companies.

The **Embedded and Intelligent Systems Laboratory** has state-of-the-art design and prototyping facilities for embedded systems design and system-processing architectures. Funded through a £140k RCIF investment by the University, it houses, amongst other equipment, several very-high-gate-count top-end FPGA boards, many processor architectures, advanced development kits and IOS/Android devices, sensor and actuators to design real-world prototypes. The Laboratory was crucial in conducting our research as part of the EPSRC funded (£457k) RoBoSaS collaboration with NASA JPL, the ESPACENET (£269k), and RESIP (£267k) EPSRC grants and the SYSIASS (£289k) and COALAS (£153k) EU ERDF grants.

Facilities II: Communications Systems

The **Optoelectronics Laboratory** houses lasers, detectors and optical components for optical spectroscopy of semiconductor devices from IR to UV wavelengths, various cryostats and kits for electronic transport measurements in semiconductor devices from T=1.3K to 300K, and electric fields up to 250 kV/cm, time resolved optical spectroscopy measurements with 100 picosecond resolution, as well as a clean room and micro-fabrication facility. Much of this laboratory was established by industrial equipment donations from Nortel and BT (worth £300k) and has been used in projects funded by EPSRC (Electrically Pumped Broadband, £328k) and EU (COST Action MP0805, £73k).

The **RF & Microwave Research Laboratory** enjoys modern equipment for developing devices to 67 GHz, including several scalar and vector network analysers, signal sources, spectrum analysers with external mixers, power meters, an atomic force microscope, a probe-station with thermal control, a test fixture, as well as design workstations with ADS and CST. This equipment (which cost in excess of £500k) was mainly obtained through EPSRC grants and SRIF funding and has been used in research projects such as the EPSRC grant on Liquid Crystal Based Beam Steerable Planar Antennas for 60 GHz Wireless Networks (£454k).

The **Access Networks Laboratory** has state-of-the-art wireless and system measurement tools. These include a top-of-the-range 100 GHz Sampling scope, a 40 GHz real-time signal analyser, a top-of-the-range 67 GHz vector network analyser, a 40 Gb/s data test-set and a 400 Gb/s optical sampling head. This equipment has been funded in part from EU grants (£175k) and in part by University infrastructure funds (£325k). The facility has been used to conduct the SODALES (£348k), FIVER (£381k) and OASE (£350K) EU projects.

The **Network Convergence Laboratory (NCL)** maintains a well-equipped research network test bed that consists of electrical and optical core networking technologies and heterogeneous wireless access networking technologies across the University campus and surrounding areas. Facilities for software-defined networks (radio or wire) and sensor networks are also available in NCL, which are used in various EU and EPSRC projects, such as EU PAL (£493k), EU PURSUIT (£282k) and EPSRC DANCER (£346k).

The **Network Multimedia Laboratory (NML)** operates as an interdisciplinary facility with a focus on research and development for efficient deployments of ultra-high-definition multimedia applications over networks. Its £1.4m RCIF-funded facilities include a set of 4K, 3D projectors and a set of high-resolution audio equipment associated with it, and a set of 8K projectors. Each is connected locally to a cluster of high-performance servers for video rendering and to the outside world via 10 Gigabit Ethernet and high-speed optical fibres. This equipment is used in the EPSRC and EU projects such as VISIONAIR (£175k).

Staff also make use of **other infrastructure available across the University** such as the UK Data Archive, which houses the UK's largest collection of datasets in social sciences and humanities. Such datasets are important for the UoA's work in machine learning and data analysis as well as growing research in the area of **big data and text analytics**.

(c)   Operational and Organisational Infrastructure

The School's **Research Strategy Group (RSG) formulates and implements the School's research strategy**. This group consists of the Head of CSEE, the Research Directors of CSEE and DMS, and representatives from the various UoA research themes and areas. RSG's role is (i) to critically appraise the research undertaken within the UoA; and (ii) to track external drivers such as RCUK priorities and national and international research agendas. RSG aims to identify long-term trends, emerging areas and challenges in order to steer and position the UoA to respond

most effectively to these changes. RSG acts as a formal link between the UoA and the University's Research Committee and the REO, and it provides critical support in the preparation of research proposals, assisting their development with seed money allocated on a competitive basis through a dedicated Research Innovation Fund. Over the period 40 nascent projects have been supported in this way with a total value of over £200k.

The **University** regards research as key to its mission and provides extensive central support for it. The **Pro-Vice-Chancellor (Research)** is responsible for the University's policy and strategy on research, knowledge exchange and enterprise. The PVC chairs the University's **Research Committee** (URC). URC has responsibility for: research strategy at University and departmental levels; the University's research performance; and establishing and promoting models of good practice for the management of research at departmental level and ensuring that all departments have suitable structures in place. URC engages with the departmental research committees, monitoring research grant activity and the strategic deployment of centrally provided resources. The PVC monitors the research performance and plans of all research active staff across the University on a biannual basis, in discussion with the Faculty Executive Deans, Heads and Research Directors. For its own research-support purposes, each Department receives: (1) a fraction of the HEFCE QR income it earns; (2) a share of a cross-University 'Research Promotion Fund' (RPF); and (3) approximately half of the indirect-cost component of research grants won, with a further 10% going directly to the principal investigator. In addition, for academics who succeed in winning external research funding for a proportion of their salary, there is a scheme that returns a substantial proportion of the funded salary to academic departments as an additional resource allocation to provide for teaching and administrative buy-out of the academic. The PVC is also responsible for approving research leave proposals, and monitoring outcomes.

The Research and Enterprise Office provides unified and comprehensive support for pre- and post-award external research grant activity, and for 'third-stream' research applications including knowledge-exchange and commercialisation. A team of Research and Enterprise Managers provide expert advice on funding sources; support with preparing research proposals; support for faculties in providing opportunities for collaborative research brainstorming; training events; links to external bodies and research funders. The REO, through the **Research Governance and Planning Manager**, also facilitates the development and implementation of research governance and ethics policies; provides training on good research practice and research integrity; advises staff and students on research governance and ethics review requirements; and ensures that research is undertaken in compliance with legislation and funders' requirements.

e. Collaboration or contribution to the discipline or research base

(a)   Academic leadership

The UoA members have made a substantial contribution to the infrastructure of the discipline by providing leadership to key academic journals via **Editor** positions (4), including the Founding Editor-in-Chief of *IEEE Transactions on Computational Intelligence and AI in Games*, and **Associate Editor** positions (19, including 8 IEEE Transactions). UoA11 staff are also members of 32 editorial boards of high-quality international journals and have edited/co-edited 7 guest issues.

The significance and excellence of the UoA's research is also exemplified by the high number of **keynote talks** that its members have given at key scientific events such as Lucas' keynote at the *IEEE Congress on Evolutionary Computation 2010* and Yang's keynote at the *11th IEEE International Conference on Ubiquitous Computing and Communications* (IUCC-2012). Overall, 57 keynotes where given.

Other distinctions include: Adams is an IET Inspec Ruby Author; Hagras was awarded an IEEE Fellowship, 2013 Outstanding Paper Award in *IEEE Transactions on Fuzzy Systems* and the 2011 UK Best KTP for London and the East Region; Lucas won Best Paper in the IEEE CIG 2012, the British Computer Society 2012 Machine Intelligence Prize for Rapidly Adapting Game Agent, and the Unconstrained Multi-objective Evolutionary Algorithm Competition in CEC 2009; Citi was awarded first prize in the *Computing in Cardiology Conference* for his work in Predicting in-hospital mortality risk of ICU patients; Higgins was awarded the Premio Peano 2013 for the most readable book on Mathematics in Italian; Poli received the Best Paper Award for GECCO's 2008 Genetic Programming Track; Walker received the Best Paper Award at IEEE CONTEL 2013; Zhang won the *IEEE Transactions on Evolutionary Computation* Outstanding Paper Award in 2009 and was

the supervisor of the best Student Paper Award in the *Congress of Evolutionary Computation* 2011. Overall, the UoA11 staff received 12 best paper awards and 23 other distinctions.

Members of the UoA have also made significant contributions taking on leading roles in **conference and other major events organisation**. For instance, Gu has served as the Program Chair, tutorial and workshop chair, and publicity chair in the organising committees of 13 IEEE international conferences, and he has been special-session chair in 15 IEEE conferences while also serving as a Program Committee member in over 100 international conferences. McDonald-Maier was the Chair of the 4th *Intl Conf. on Emerging Security Technologies* (2013). Lucas was Program Co-Chair of the *IEEE Conf. on Computational Intelligence in Games* (2011, 2012). Poesio was the Chair of the *Association for Computational Linguistics* (ACL) Conference (2013). Hagras was Co-Chair of the 2011 & 2013 *IEEE International Symposium on Intelligent Agents* and the 2011 *IEEE International Symposium on Advances in Type-2 Fuzzy Logic Systems*. Hu was Chair of the 2011 *IEEE International Conference on Mechatronics and Automation*, General Co–Chair, of the 2009, 2010 and 2011 IEEE *International Conference on Information and Automation* and the 2011 *IEEE/CME International Conference on Complex Medical Engineering*. Overall, UoA11 staff have contributed on various organising roles to more than 120 conferences and other events.

Members of the Essex UoA 11 play key roles in **scholarly networks and key associations**. Hagras is the Chair of the IEEE CIS Task Force on Extensions to Type-1 Fuzzy Sets (2006-*present*) and Vice-Chair of the IEEE CIS Technical Committee on Emergent Technologies (2009-*present*). Henning served on the EPSRC ICT Strategic Advisory Team (2006-10) as well as on multiple EPSRC panels. Hu was a founding member of IEEE Robotics and Automation Society. Poli was a member of the executive committee of ACM's SigEVO (2007-2013). Lausen is president of the Gesellschaft für Klassifikation e.V. (GfKl). Overall, UoA11 staff have contributed to 24 scholarly networks and 32 scientific associations.

(b) Cross-institutional collaboration

During this period, members have engaged in extensive collaborative activities and well over half of the UoA's publications in this period were co-authored with external collaborators, many of them abroad. Examples of specific cross-institutional collaborations include:

- The EPSRC-funded Global Engagement Project: collaboration with the NASA Jet Propulsion Laboratory (contact Adrian Stoica, Head Advanced Robotics Group) and the European Space Agency (contact David Merodio, ESTEC).
- The ERDF Projects SYSIASS and COALAS: collaboration with several partners in Canterbury, Lille, Amiens and Rouen.
- The EPSRC-funded RESIP and ESPACENET projects: collaboration with partners in Edinburgh, Surrey as well as many leading industrial companies.
- The EPSRC-funded AutoAdapt project: collaboration with the Open University, Robert Gordon University, the Centre of Research and Technology (Thessaly, Greece) and Kodak.
- UoA staff are members of 5 EPSRC collaborative networks.
- 10 collaborative EU FP7 projects where awarded during the census period.

(c) Major strands of interdisciplinary research

Members of the UoA11 collaborate extensively with scholars from other disciplines both within and outside the Institution. The UoA11 plays a major role in interdisciplinary areas, signified by its four Centres. A specific exemplar is the area of **Assisted Living Technologies**, a focus area where many members of the UoA work interdisciplinary with staff from Biological Sciences, Psychology, and Health and Human Sciences on a series of challenges that are directed to improving assisted living technologies and care with the users' needs in mind.

A significant part of the work in **Human Language Understanding and Technology** (Fox, Poesio) sits at the intersection of Computer Science, Language and Linguistics, Philosophy and Logic. The group works closely with the University of Essex based UK Data Archive (UKDA) on information extraction, text mining to support visualisation and automated analysis of the logs of the queries to the UKDA site. In the area of **Computational Finance and Economic Agents**, staff work closely with members of other academic departments such as the Essex Business School and Economics (Fasli, Tsang, Phelps), while recently emerging work in **complex socio-cognitive systems** and **global systems science** requires close collaborations with Sociology, Economics and Government.