Institution: University of Hertfordshire

Unit of Assessment: Panel B (11): Computer Science and Informatics

a. Overview

Computer Science research at the University of Hertfordshire (UH) is carried out within the Science and Technology Research Institute (STRI). The STRI is a multidisciplinary research facility that provides purpose-built, dedicated laboratories incorporating accommodation for research staff (including staff from other institutions on extended visits) and research students. It also provides the research infrastructure, including administrative support, access to intellectual property and contract support, as well as financial management and planning. Academic staff are based in adjacent conventional departments (primarily in the School of Computer Science). This structure has produced a vibrant research culture, with close interaction between students, postdoctoral researchers and academic staff.

An Institute Management Group oversees the STRI, which consists of four research centres. One of these is the Centre for Computer Science and Informatics Research (CCSIR), led by Professor Bruce **Christianson**. It comprises four research laboratories: Adaptive Systems, Algorithms, Biocomputation, and Compiler Technology and Computer Architecture.

b. Research strategy

Relation to the strategy described in RAE 2008

In line with the university's Research Strategy 2011–15, the CCSIR's research strategy has prioritised areas of existing excellence, focusing on quality rather than quantity. In RAE 2008, 15% of CCSIR research activity was classified as world-leading. A key strategic aim has been to continue reinforcing the research areas that produced this world-leading research output and consequently raise the CCSIR's and the university's international profile. The strategy has included making new staff appointments in Adaptive Systems, Biocomputation, and Compiler Technology, attracting talented, relatively junior, staff from leading universities (for example, UCL and the Universities of Vienna and Karlsruhe) and giving them opportunities to develop into research leaders. This strategy has been vindicated, as evidenced by these new staff securing external funding (grants with a total value to CCSIR of £3.5M from BBSRC, EPSRC and FP7, two of which are coordinated by CCSIR) and publication in high-impact journals such as *Nature*. Staff selection is governed by research track records and the ability to interact with the existing research groups; this maintains a critical mass in areas of strength and ensures a productive research culture.

The current submission includes 27.4 full-time equivalent (FTE) staff members, which constitutes a small increase on the 25 FTE staff in RAE 2008. The development of a thriving research environment is further facilitated by the allocation of dedicated QR funding, guided by detailed Research Delivery Plans that allocate internal funding based on planned and achieved annual deliverables, such as research outputs and external grants. All of the QR funding from RAE 2008 has been reinvested into research, including PhD studentships (50%), dedicated research staff salaries (33%), and equipment and travel funding for research staff and PhD students (17%). Additional university capital has been used to fund state-of-the-art facilities such as a Robot House and a large computer cluster. These major investments have proved vital support for novel research in the four laboratories. The dissemination and exploitation of research and the leveraging of research impact have also been stimulated by allocating smaller and medium size grants (up to £25,000 each), provided by the university via the STRI to open up new avenues through small, novel and explorative projects. Moreover, facilitated by the university's business-facing agenda, a further increase in research impact has resulted from the successful and extensive Knowledge Transfer Partnership (KTP) programmes pursued by CCSIR.

Implementation of the strategy by the research laboratories

Adaptive Systems Laboratory: At the time of the RAE 2008 submission, research in Adaptive Systems was the major element of the Systems Engineering Laboratory. Adaptive Systems has now matured and expanded into its own laboratory, coordinated by **Dautenhahn** and comprising

five distinct but collaborating teams: Embodied Social Intelligence and Interaction (**Dautenhahn**); Sensor Evolution, Perception, Information and Actuation (**Polani**); Rehabilitation Robotics and Assistive Technology (**Amirabdollahian**); Enactive Intelligence (**Nehaniv**); and Embodied Affective and Autonomous Robotics (**Cañamero**). As well as advancing basic scientific knowledge in artificial intelligence, artificial life and social robotics, the laboratory targets real-world applications, such as robot-assisted therapy for children with autism (the KASPAR project), and developing assistive tools and rehabilitation systems to support the elderly at home. The latter is an important topic due to recent demographic changes and an ageing population, and it is a growth area of research, supported by the appointment of a new staff member and the award of two major European grants that are coordinated by CCSIR. The work has been acknowledged by policy makers, with KASPAR featured in a Department of Health parliamentary report on research and development work relating to assistive technology 2009–10. It was one of the projects included in the Research Councils UK and Universities UK 'Big Ideas For the Future' report. Adaptive Systems Laboratory research has received extensive coverage in the *New Scientist*, *Guardian*, BBC and Channel 4 and other media, and has been disseminated to the public through exhibitions in, for example, the London Science Museum. The continued growth of Adaptive Systems research will also contribute to CCSIR's aim to increase the international visibility and impact of our work.

Algorithms Laboratory: Research in the Algorithms Laboratory (coordinated by **Christianson**) focuses on the representation, analysis and transformation of algorithms abstracted from a number of application domains. The laboratory grew out of the Hatfield Numerical Optimisation Centre (NOC), an international centre of excellence led by Emeritus Professor Laurence Dixon and operational for more than 30 years, undertaking research into high performance algorithms running on state-of-the-art architectures. Current research areas include software defect prediction (**Bowes**), computer networks and security (**Xiao**, **Christianson**), algebraic methods (**Nehaniv**), automatic differentiation (**Christianson**), biometrics (**Ariyaeeinia**), and optical network protocols (**Senior**, **Kourtessis**). Future research in this laboratory will explore algorithms based on non-traditional computational foundations, such as the use of graph-theoretical, semi-ring-based algorithms for solving constraint-satisfaction problems arising in subtype inference, and the application of algebraic methods to representation problems in quantum computing, and to communication systems involving both dynamic reconfiguration and dynamic bandwidth assignment, as well as various areas of artificial intelligence, biological networks and machine learning. This collaborative area of research is identified as a key area of growth.

Biocomputation Laboratory: Research involves applying computational methods to biological problems and developing computational techniques based on inspiration from biology. Research is coordinated by **Steuber** and falls into the subject areas Computational Neuroscience (**Steuber**), Machine Learning (**Davey**), Computational Systems Biology (**Schilstra**), Computational Algebraic Biology (**Nehaniv**), and Bioinformatics (**te Boekhorst**). Biocomputation Laboratory members develop computational models at different levels of complexity, and collaborate closely with leading experimentalists in the UK and abroad. The laboratory's strategic aims in RAE 2008 were to strengthen the link between computer science and biology, and to establish new collaborations with experimental laboratories. These aims have been fully achieved. For example, through a BBSRC Systems Biology Fellowship, the Computational Neuroscience Team has engaged in an international collaborative initiative to understand neural coding in the cerebellum, a part of the brain that is involved in motor control, and a collaboration with UCL has resulted in a publication in *Nature*. One current goal is to strengthen the research impact by applying the emerging computational models to an increasing range of medical research, engineering, and in collaboration with industry. Several new projects investigating health-related topics such as epilepsy, ataxias and ageing are underway, and a novel avenue currently being explored in collaboration with Tesco's IT department involves the application of biologically inspired models and Biocomputation software to optimising supermarket checkout processes.

Compiler Technology and Computer Architecture Laboratory (CTCA): Established by **Shafarenko** post-RAE 2008, the laboratory specialises in programming paradigms, languages and compilation/run-time support systems for distributed, embedded and multicore computing. The laboratory's mission is to bring complex program analysis occurring in sophisticated type systems and programming logic down to the level of practical compilation tools for efficient distributed

parallel computing. The specific strategy is to engage with industry (including multinationals such as SAP and Philips) within EU Framework projects in order to solicit requirements from them on the one hand and obtain feedback (in terms of usability and performance) on research outcomes on the other. In line with CCSIR's strategy of developing areas of existing strength, the CTCA was reinforced by **Kirner**'s appointment in 2010. **Kirner** leads the Embedded Computing Team, which pursues research on the development of systems with ensured properties under resource constraints. This is high-priority research, as society will increasingly rely on services provided by devices with embedded computing systems, and therefore another key area for future growth.

Future strategic aims

We will continue our established policy of developing strength in depth. A major aim is to continue raising our international profile through the usual means of increased international collaboration and continuing both to assume academic leadership roles and contribute to international societies and professional bodies. A significant part of our success has come from interdisciplinary research that combines expertise from computer science with disciplines such as biology, psychology and engineering. We will build on this strength by expanding our existing interdisciplinary research areas and exploring new collaborations with partners from outside computer science. Research in the Adaptive Systems and Biocomputation laboratories falls into national and international strategic priority areas such as healthy ageing, computational approaches to neuroscience and mental health (HORIZON 2020 strategic priorities), and systems biology (BBSRC strategic priority).

Our second major goal is shaped by the university's strategic aim to lead the next generation of business-facing universities: we will continue to increase the industrial exploitation and extra-academic impact of our research. This aim is pursued by strengthening our connections with research users outside academia. We will extend our collaborations with local and global industry, expand the number of our already very successful Knowledge Transfer Partnership (KTP) programmes, and investigate additional possibilities to engage with the business world and the public sector. A further benefit to the impact of our research will result from continued engagement with the media, policy makers and funding organisations such as the Technology Strategy Board.

c. People, including:

i. Staffing strategy and staff development

To increase CCSIR's world-leading and internationally excellent research, new staff have been recruited to strengthen Adaptive Systems, Biocomputation, and Compiler Technology and Computer Architecture. An important selection criterion in making appointments is that new staff can act synergistically with existing research activities in our areas of strength. The appointment of **Steuber** in the Biocomputation Laboratory, who was brought in from University College London in 2007 as a potential future successor for Prof. Rod **Adams**, has been followed by appointments in Adaptive Systems (**Amirabdollahian**, from Salford) and Embedded Computing (**Kirner**, from the University of Vienna). Since their initial appointments into junior or mid-range positions, these staff have now taken on leadership roles (**Steuber**: Head of the Biocomputation Laboratory; **Amirabdollahian**: Leader of the Rehabilitative Robotics Team; **Kirner**: Leader of the Embedded Computing Team). All three have also been promoted to Reader and have secured external funding: BBSRC (**Steuber**), EPSRC (**Amirabdollahian)** and EU (**Amirabdollahian**, **Kirner**).

As well as the competitive recruitment of new academic staff with leadership potential, CCSIR recruits postdoctoral researchers from leading institutions worldwide. The large number of early career researchers (approx. 20 postdocs and 60 PhD students) is complemented by the presence of experienced staff members such as **Christianson**, **Dautenhahn**, **Davey**, **Nehaniv**, **Polani**, **Schilstra**, **Senior**, **Shafarenko**, ensuring a combination of vitality and sustainability. The strength of our staff support, and the excellent training that our postdoctoral researchers receive, is reflected by academic staff and postdoc destinations when they leave us. Previous staff and postdocs are now professors at Heriot-Watt University, Edinburgh (Scholz); the Max Planck Institute for Complex Systems Dynamics in Magdeburg (Marwan); the University of Karlsruhe (Wegner) and the Hutchinson Cancer Research Center, Seattle (Boulouri). Others are: Reader, Brunel University (Hall); Assistant Professor, University of Amsterdam (Grelck); Staff Scientist at

the European Bioinformatics Institute (EBI), Cambridge (Keating); and Research Fellows at the University of Oxford (Thiagalingam) and the École Normale Supérieure Paris (Maex).

The CCSIR has long-standing internal procedures for research staff career development. New appointees are supported by a mentoring scheme. Generous research allocations (typically 70% of staff time) are given to 'new-blood' appointments in the key research areas; these are usually limited to an initial three years, after which the staff member has to provide evidence of sufficient research output and external funding to maintain the research allocation. Annual appraisal within the School of Computer Science provides an opportunity to reflect on research progress and, with a senior member of staff, formulate future plans. Since 2008, these procedures have resulted in readerships being awarded to **Polani**, **Steuber**, **Kirner** and **Amirabdollahian**.

In April 2010, the university launched the Concordat to support the career development of researchers and later in the same year it was one of the first universities to receive the European Council HR Excellence in Research Award. It received external re-approval of the Award after its two-year review in 2012. The key principles to which the university adheres include the recruitment, selection and retention of researchers with the highest potential (e.g. **Steuber**, **Amirabdollahian**, **Kirner** in CCSIR), and the promotion of diversity and equality in recruitment and career progression. CCSIR's commitment to equality and diversity is reflected by the success of female researchers at all levels, including prominent staff members such as **Dautenhahn**, **Cañamero**, **Schilstra**, **Xiao**, **Helian**, **Sun** and **Carvalho**. Applications from under-represented groups are encouraged, and since 1 January 2008, 13 of the School's 30 new permanent staff have been female. In developing its approach to staffing and staff recruitment, CCSIR is supported by the university's Equality Office and Disability Services, which advise on legal issues surrounding equality and disability, and on best practices. The university is a member of the Athena Swan Charter and is a Stonewall Diversity Champion, and will be participating in a national survey exploring cultural and gender issues in STEM. The university participated in the 2010, 2011 and 2013 Careers in Research Online Survey (CROS). The 2013 results show that in 12 out of 18 categories UH responses are above or more positive than the national average. The survey provides valuable feedback to the unit on its staff development strategy.

Under the Concordat's aegis, CCSIR researchers have opportunities for training and career development in all four domain areas. The university has research student and staff fora at both Doctoral College and Research Institute level, to help identify and support individual development needs. These allocate funding resources such as, for example, additional internal funding that enabled us to specifically target leadership development for researchers. All research staff are given central and local induction and are encouraged to access the academic staff development programme as well as the Generic Training for Researchers (GTR) programme.

ii. Research students

Every year, the CCSIR recruits approximately ten PhD students. We have continued our policy of selectively recruiting highly qualified research students in our key research areas, where they will receive strong support. Given the interdisciplinary nature of much of our cutting-edge Computer Science research, the students come from a range of backgrounds including computer science, physics, mathematics, engineering and natural sciences. We advertise widely through a number of different channels, including jobs.ac.uk, *Nature*, professional organisations and specialist mailing lists. In a typical year, application numbers exceed the offered places by a factor of ten, and successful candidates typically have the equivalent of a UK MSc degree with distinction. Research students are selected through a panel interview and in-depth discussions with potential supervisors. Our selective and supportive approach is vindicated by a very successful track record, which includes recently graduated PhD students working at Google, Intel Labs, Dolby, Blackberry, Génération Robots, Alcimed; and as assistant professors (University of Skovde, Sweden; University of Debrecen, Hungary) and postdoctoral research fellows (University of California, Irvine; UCLA; University of Freiburg; Okinawa Institute of Science and Technology, Japan; Albert Einstein College of Medicine New York; London School of Economics; Wellcome Trust Centre for Neuroimaging, UCL; Montefiore Research Institute, Belgium, Karolinska Institute, Stockholm).

Each PhD student is assigned a principal supervisor and at least one (typically two) second supervisor(s), who must collectively have both research area expertise and experience of doctoral supervision. New and inexperienced supervisors are required to attend the university's supervisor training programme. Research student progress and supervision appropriateness are monitored on a regular basis. PhD students submit formal written progress reports and receive feedback from independent assessors during at least two progress checkpoints that precede the final *viva voce* examination. Additional monitoring and feedback opportunities are provided through annual meetings with the Computer Science Research Student Tutor. The quality of supervision and supporting administration in Computer Science is reflected by the results of the 2013 Postgraduate Research Experience Survey (PRES), with scores above the national average in all six sections, and particularly high ratings for supervisor feedback and availability (93% and 95%, respectively).

All of the approximately 60 Computer Science PhD students are physically located within the STRI, where they benefit from its research culture, seminars, training and development, and close interaction with visiting academic researchers and postdoctoral staff. The students have generous desk and storage space, a personal computer, and access to any specialist technical equipment (including a large computer cluster and a wide range of robotics systems) required for their research. There are several research seminar programmes in Computer Science, one of which (the Colloquium) is intended primarily for research students, with every student being expected to deliver at least one research centre-wide talk. Other seminar programmes and reading groups are organised by individual Research Laboratories: these include Biocomputation, Adaptive Systems and Compilation Technology seminar series with regular presentations by external speakers. Moreover, PhD students are encouraged to attend specialist MSc-level courses such as Artificial Life, Neural Computation and Distributed Systems Security, and they are offered additional subject-specific training in areas such as dynamical systems and statistics. Other vital parts of the PhD programme are attendance at summer schools and presentation at leading international conferences. A typical PhD student will be funded to present at one or two conferences annually, and to attend one summer school (such as the EU Advanced Summer School in Computational Neuroscience).

All Computer Science PhD students take part in a comprehensive programme of Generic Training for Researchers (GTR) provided through the university's Doctoral College. The programme is open to both research students and staff, and covers a variety of areas of supporting studies, including the process of research degrees, personal development, communication skills, employability, and information technology. GTR sessions support the development of a range of skills, including technical writing, statistics, teaching for research students, and many others.

d. Income, infrastructure and facilities

Computer Science research is carried out within the STRI, a 3,500 sq.m. multidisciplinary research facility offering purpose-built, dedicated laboratories incorporating accommodation for research staff (including staff on extended visits from other institutions) and research students. The STRI provides a research infrastructure that includes administrative and technical support, intellectual property and contract support, financial management and planning. It provides a vibrant research culture with close interaction between students, postdoctoral researchers, and academic staff.

Computer Science research receives consistent and generous support from central university funding. A small grants scheme provides individual researchers with relatively small amounts (20 grants of up to £25k a year) to explore novel ideas and create new avenues to enhance the impact of their research. Internal university support has also helped to develop the infrastructure required for some of the technically challenging research in the Adaptive Systems, Algorithms, Biocomputation, and Compiler Technology laboratories. One aspect of Adaptive Systems research concerns the design, implementation and study of robot companions for a home environment – suitable, for example, for elderly users. To create a realistic state-of-the-art environment for such studies, the university acquired a two-storey, off-campus residential house, situated within walking distance, and extended it with a sensor network as a 'smart home' (called the Robot House). A comparable investment of internal funds has enabled new and groundbreaking research in

Biocomputation. Research in the Biocomputation Laboratory involves the development and simulation of biologically realistic data-driven neuronal network models of the cerebellum, a part of the brain that is involved in motor control and motor learning. The development and optimisation of these models has been enabled by the acquisition of a large computer cluster with 640 state-of-the-art Xeon cores, two SMP machines with 48 cores and 256 gigabytes of RAM and 110 terabytes of storage. This facility is also used by other teams, notably the CTCA laboratory.

As well as internal support, external grant income is instrumental in attracting and funding excellent staff, and developing the infrastructure required for world-leading research. A string of external grants from the EU, UK Research Councils and international funding bodies has provided and continues to provide support for research in all four laboratories. These projects include the FP7 projects BIOMICS, SCRIPT, CORBYS, ACCOMPANY, ACCORDANCE and CRAFTERS; EPSRC projects on Automatic Differentiation (CompAD) and Robot Safety; and a BBSRC Systems Biology project, amounting to a 31% increase in total grant income spent compared to RAE 2008.

	Total income	FTE staff submitted	Income per FTE staff
RAE 2008	£ 6,560k	25	£ 262k
REF 2014	**£ 8,591k**	**27.4**	**£ 313k**

The KASPAR project, which investigates robot-assisted therapy for children with autism, has received donations from a number of foundations and charities such as the Stavros Niarchos Foundation, the Garfield Weston Foundation and the Henry C Hoare Charitable Trust (total donations £560k). This external grant income is essential for developing the required research environment, including highly complex human-sized and partially humanoid robots (iCub, 2 Care-O-bot® 3 robots, equipment worth about €1 million in total), equipment for motion and eye tracking, as well as for setting up and analysing human–robot interaction experiments.

An experienced central Research Grants Team supports individual academic and research staff in their efforts to obtain external research funding. They also offer help and assistance with all aspects of pre-award activities, including identifying appropriate funding sources, reviewing grant applications, endorsing grant applications on behalf of the university, and advising on the grants submission systems, costing research, and research ethics issues (the university is a full member of the RCUK Research Integrity Office). The team includes two specialist advisors on EU funding, including FP7, Horizon 2020 and non-Framework opportunities. Other central services that support Computer Science research include library and IT provision through Information Hertfordshire, and a group of specialist technical staff provide hardware and software support to the School.

CCSIR provides a wide spectrum of services to industry. These include applying machine learning techniques to predicting the skin penetration of drugs (with MedPharm (**Sun**, **Davey**, **Adams**)); evaluating software tools and requirements analyses (with 1Spatial and Isabel Hospice); developing e-learning techniques (with OnTrack); and a collaboration with Tesco that involves the application of biologically inspired models and Biocomputation software tools to the simulation of checkout processes (Netbuilder': **Schilstra**, **Davey** and **Steuber**). Joint projects with industry are often funded through Knowledge Transfer Partnerships (KTPs) and collaborative grants from the Technology Strategy Board. The CCSIR has secured funding for recent KTP partnerships with companies such as e2E Services (**Kirner**, £170k), Portfolio Metrica (**Lane**, £139k), Europa Science (**Rainer**, £152k), Games for Life (EPSRC three-year iCase studentship, £87k), Acoustical Control Engineers (£180k), International Labmate and others, amounting to a total income of £1,330k since 2008.

e. Collaboration or contribution to the discipline or research base

Collaborations

Computer Science research at CCSIR benefits from the cross-fertilisation between different disciplines and the involvement of researchers from various backgrounds including, beyond core computer science, mathematics, physics, biology, psychology, engineering and medicine. The interdisciplinary nature of Computer Science research is supported by collaborations within the

interactive research environment provided by the STRI, with the university's other two research institutes, and with leading laboratories and industrial partners in the UK and abroad. Collaborative research projects, typically funded by external grants or contracts, are core activities of all four CCSIR research laboratories. Exemplars of interdisciplinary collaborations include:

- ACCOMPANY: A consortium including eight leading academic and technological partners such as the Fraunhofer Institute (Germany), MADoPA (France), and external advisors from industrial partners including SCHUNK (Germany). The project, coordinated by CCSIR (**Amirabdollahian**), pursues interdisciplinary research in areas of robotic companions for the elderly at home.
- SCRIPT: A multidisciplinary collaboration between clinical, industrial robotics and computer science groups that follows a user-centred design approach towards forming a home rehabilitation device. The project is coordinated by CCSIR (**Amirabdollahian**), funded by an FP7 grant and involves seven European partners in academia and industry.
- BIOMICS: A collaboration with mathematicians, biologists and computer scientists at the Universities of Debrecen, Passau and Dundee that is funded by an FP7 grant on Unconventional Computation and coordinated by CCSIR (**Nehaniv**, **Schilstra**, **Christianson**).
- VESTICODE: A consortium that includes computational neuroscientists at CCSIR (**Steuber**), statistical physicists at the Université Paris Descartes, and electrophysiologists at the Ecole Normale Supérieure, the Pasteur Institute in Paris and University College London. The project is funded by a Systems Biology Fellowship from the BBSRC and the ANR (France) and involves the development of computational models to study neural coding in the cerebellum.
- CORBYS: An FP7 integrated project with the purpose of developing a cognitive integrated architecture. CCSIR (**Polani**) provides the cognitive core for this project with a first-principles, biologically inspired cognitive model. The demonstration scenarios include a rehabilitative robotics scenario and a joint human–robot exploratory scenario. The project involves eleven European partners, among them five industrial and two clinical partners.
- A-LIZE: An FP7-funded project that includes CCSIR (**Cañamero**) as part of a European consortium of nine partners from academia, industry (France) and end-user groups (a hospital in Italy). This interdisciplinary project brings together different aspects of the theory and practice behind embodied cognitive and affective robotics to develop robot companions that support the training, therapy and wellbeing of diabetic children undergoing hospital treatment, and that are capable of maintaining believable any-depth affective interactions with young users over an extended and possibly discontinuous period of time.
- LIREC: An FP7-funded collaboration between CCSIR (**Dautenhahn**), the Swedish Institute for Computer Science, the Portuguese Instituto de Engenharia de Sistemas e Computadores, Investigacao e Desenvolvimento, five universities and two companies spread across seven European countries. The project brings together ethology, social science, design and computer science to design digital and interactive robot companions.
- RoboSKIN (**Dautenhahn**): An FP7-funded consortium of six European partners that aims to develop a range of new robot capabilities based on the tactile feedback provided by a robotic skin from large areas of the robot body**.**
- ITALK (**Nehaniv**): A collaboration between six European laboratories, MIT (USA) and RIKEN (Japan) funded by an FP7 grant. The project aims to develop artificial embodied agents able to acquire complex behavioural, cognitive and linguistic skills through individual and social learning.
- ACCORDANCE (**Kourtessis**, **Senior**): An FP7-funded project with eight partners, including Deutsche Telekom, Telefonica, Alcatel-Lucent and Karlsruhe Institute of Technology, concerned with designing and implementing a high-capacity, long-reach passive optical network.
- EvoSN (**Steuber**): A collaboration with the Evolutionary Systems Laboratory at Adam Mickiewicz University Poznan, Poland, that involves the evolution of spiking neural networks for fundamental computational tasks and robot control (funded by the Polish National Science Centre).
- Open Source Brain (OSB): An initiative that aims to create a public repository of models to enable collaborative modelling in computational neuroscience, inspired by open source software repositories such as SourceForge. Coordinated by UCL and funded by the Wellcome Trust and the International Neuroinformatics Coordinating Facility (INCF), it involves 30 laboratories and

companies in 11 countries. CCSIR (**Steuber**) is one of the initiative's seven founding members.

Other externally funded interdisciplinary projects involving collaborations with international universities, research institutes and industry and falling into the period since 1 January 2008 include FP6 projects RobotCub (**Dautenhahn**), eCircus (**Dautenhahn**), IROMEC (**Dautenhahn**), FEELIX-GROWING (**Cañamero**), and OPAALS (**Nehaniv**). OPAALS evolved out of a longstanding collaboration with Prof. John Rhodes (Mathematics Department, University of California, Berkeley) that informs the development of computer algebraic methods and software to carry out Krohn-Rhodes decompositions and applications to systems biology models. These models were developed with the collaboration of Dr Sonia Lain and Dr Inge van Leeuwen (Karolinska Institute, Sweden) and cancer clinician Prof. Alastair Munro (University of Dundee). This has resulted in a new computational algebraic approach to various problems in biology and medicine, and CCSIR (**Nehaniv**) has developed the SgpDec open-source software now used worldwide to carry out decompositions for predictive manipulation of complex systems (e.g., by Dr Simon DeDeo's group at Santa Fe Institute, USA and Prof. Jim Crutchfield's group at University of California, Davis).

Members of the Biocomputation Laboratory (**Steuber**, **Davey**) are involved in an interdisciplinary project with Prof. Jim Bower (Barshop Institute for Aging Studies and University of Texas San Antonio) concerned with computational implications of altered neuronal morphologies during ageing, and in a collaboration with Dr Freek Hoebeek and Prof. Chris De Zeeuw at Erasmus Medical Center Rotterdam that investigates the neuronal mechanisms underlying epileptic absence seizures. Other interdisciplinary collaborations include modelling the skin penetration of drugs (**Davey**, **Sun**, **Adams**, with the Department of Pharmacy and the company MedPharm); the development of stochastic simulation tools (**Schilstra**, with Prof. John Correia at the University of Mississippi Medical School); the identification of regulatory sites in DNA (**te Boekhorst**, **Davey**, **Sun**, **Adams**, with Dr Irina Abnizova at the Wellcome Trust Sanger Institute Cambridge and Dr Mark Robinson at Benaroya Institute, Seattle); the development of software for cognitive modelling (CHREST, **Lane** in collaboration with Prof. Fernand Gobet at Brunel University); and the application of machine learning techniques to the prediction of galactic movements (**Sun**, **Adams**, **Davey** and **Lane** with the School of Physics, Astronomy and Mathematics). These interdisciplinary collaborations benefit CCSIR by generating publications in high-impact journals such as *Nature*, *Journal of Physiology*, *European Journal of Neuroscience*, *Cerebellum*, and *Monthly Notices of the Royal Astronomical Society*, and they often lead to future funding applications.

Many collaborations are informed by research users in industry. For example, the Compiler Technology and Computer Architecture Laboratory (**Shafarenko**, **Kirner)** engages with multinationals such as Philips and SAP to solicit requirements and receive feedback about the usability and performance of their research outputs. These collaborations are funded by the European Framework projects ADVANCE (coordinated by CCSIR), AETHER, APPLECORE and CRAFTERS and involve other laboratories at Imperial College; University of Amsterdam; University of California, Irvine; Tampere University of Technology; Aalborg University; Université Libre de Bruxelles; Universidad Cantabria; and others. The FP7 CRAFTERS project (**Kirner**) involves 20 industrial partners, including Infineon Technologies, Rapita Systems, Thales Italia, Integrasys SA, Altreonic, Hi Iberia Ingenieria and Synopsis, with the goal of establishing a resource-efficient development process with tool support for embedded systems on many-core platforms. Research user feedback is also important for projects in other areas. For example, a hospital (HSE, Italy) and an SME (GOSTAI, France) are actively involved in testing robot prototypes in the A-LIZE project (**Cañamero**); and two SMEs (Entertainment Robotics and Aldebaran Robotics) have contributed to the FEELIX-GROWING project (**Cañamero**). Moreover, the innovative use of machine learning techniques and data handling by the Machine Learning Team (**Davey**, **Sun**, **Adams**) is mainly driven by the needs of the applications supplied by collaborators. For instance, the unbalanced nature of the genomic data led to the innovative use of data-driven techniques coupled with support vector machines, and the sparsity of the data on drug transport through the skin led to a careful choice of methods that produced a new and much improved prediction algorithm.

Academic leadership

Members of the CCSIR contribute to the Computer Science research base through leadership in the international community. Some of these services to the community are longstanding and show

past sustainability. Others are new, demonstrating that this is likely to continue into the future.

Chairing conferences: All our research staff are programme committee members, and a number act as programme chairs at conferences, e.g., the 9th International Conference on Epigenetic Robotics (**Cañamero**, Venice, Italy, 2009), the 21st International Security Protocols Workshop (**Christianson**, Cambridge, UK, 2013), the 2nd International Symposium on New Frontiers in Human–Robot Interaction (**Dautenhahn**, Leicester, 2010), the 3rd ACM/IEEE International Conference on Human–Robot Interaction (**Dautenhahn**, Amsterdam, 2008), the IEEE Symposium on Artificial Life (**Nehaniv**, Nashville, USA, 2009; Paris, France, 2011; Singapore, 2013), the International Conference on Information Processing in Cells and Tissues (**Nehaniv**, Ascona, Switzerland, 2009), and the OSA Optics and Photonics Congress (**Kourtessis**, USA, 2012).

Keynote talks: Many staff members have been invited to give keynote talks at workshops and conferences, such as the workshop 'The Role of Emotion in Adaptive Behaviour and Cognitive Robotics' at the 10th International Conference on Simulation of Adaptive Behavior (**Cañamero**, Osaka, Japan, 2008); the Research Symposium 'T100 – Celebrating 100 years since the birth of Alan Turing' (**Dautenhahn**, Edinburgh, 2012); International Conference on Playware and Robotics (**Dautenhahn**, Copenhagen, 2010); 4th IEEE Conference on Cognitive Infocommunications (**Dautenhahn**, Budapest, 2013); Future Concept and Reality of Social Robotics Event (**Dautenhahn**, Brussels, 2013); Workshop on Exploring the Fitness and Evolvability of Personal Learning Environments (**Nehaniv**, France, 2011); Abstract Algebra and Algorithms Conference (**Nehaniv**, Eger, Hungary, 2011); IEEE Symposium Series on Computational Intelligence (**Nehaniv**, Singapore, 2013); Santa Fe Institute Workshop on Perception and Action (**Polani**, Santa Fe, USA, 2010); DAMP workshop at the programming language conference POPL (**Shafarenko**, Austin, USA, 2011); 10th PTBI Workshop on Bioinformatics (**Schilstra**, Gdansk, Poland, 2012); International Workshop 'Multi-Scale Modeling in Computational Neuroscience' (**Steuber**, Lübeck, Germany, 2012); EvoDevoNet workshop (**Steuber**, Poznan, Poland, 2012); 3rd IEEE Photonics Global Conference (**Senior**, Singapore, 2012); and the Future Networks and Mobile Summit (**Kourtessis**, Lisbon, 2013).

Editorships: CCSIR members act as: editor-in-chief, *International Journal Interaction Studies – Social Behaviour and Communication in Biological and Artificial Systems* (**Dautenhahn**); and as editors of journals such as *Interaction Studies* (**Cañamero**, **Nehaniv**), *Optimization Methods and Software* (**Christianson**), *Biosystems* (**Nehaniv**), *International Journal of Advanced Robotic Systems* (**Nehaniv**), *Journal of Autonomous Agents and Multi-Agent Systems* (**Polani**), *Advances in Complex Systems* (**Polani**), *Paladyn Journal of Behavioral Robotics* (**Polani, Nehaniv**), *PLoS One* (**Schilstra**), *European Transactions in Communications* (**Senior**), *Photonic Network Communications* (**Senior**), *International Journal of Parallel Processing* (**Shafarenko**), *Frontiers in Neuroinformatics* (**Steuber**), and *Frontiers in Systems Neuroscience* (**Steuber**). Other editorships include: a new book series on Humanoid Robotics (co-edited by **Cañamero**, Atlantis Press); the book *New Frontiers in Human-Robot Interaction* (edited by **Dautenhahn**, John Benjamins Publishing); and *Springer Encyclopedia of Computational Neuroscience* (section editor, **Steuber**).

Memberships of committees and taskforces: include the IEEE/CIS taskforce on artificial life and complex adaptive systems (chaired by **Nehaniv**); UK taskforce for robotic standardisation (**Amirabdollahian**); Board of Trustees, RoboCup Federation (**Polani**); HiPEAC network of excellence in High Performance Computing (**Shafarenko**); IFIP Working Group 10.3 'Concurrent Systems' (**Shafarenko**); Multi-scale Computational Neuroscience Working Group of the National Institutes of Health USA (**Steuber**); Scientific Committee of the Latin American School on Computational Neuroscience (**Steuber**); and the Board of Directors and Executive Committee of the Organization for Computational Neurosciences (**Steuber**).

Other esteem indicators: include Elected Senior Memberships of IEEE (**Shafarenko** since 2005, **Dautenhahn** and **Nehaniv** since 2013); and panel speaker at the Rise of the Machines event organised by the Royal Society during their 350th anniversary celebrations (2010) (**Dautenhahn**).