Institution: University of East Anglia

Unit of Assessment: 11 Computing Sciences and Informatics

a. Overview

The School of Computing Sciences is located in the Faculty of Science of the University of East Anglia (UEA). Its research activity is formally grouped into three "laboratories": **Computational Biology**, **Machine Learning and Statistics**, and **Graphics, Vision and Speech**. This structure brings together researchers who work in related areas and who use similar research techniques, although there is considerable interaction across the three labs.

Much of the School's research involves collaboration with other UEA Schools, notably the Schools of Biological Sciences, Environmental Sciences, and History, and with the Research Institutes of the Norwich Research Park (NRP). The NRP is a unique cluster of researchers located within six partner institutions: UEA; three BBSRC-funded research institutes (Institute of Food Research, John Innes Centre, Genome Analysis Centre); the Sainsbury Laboratory; and the Norfolk and Norwich University Hospital (NNUH). The Genome Analysis Centre (TGAC) opened in 2009 and hosts one of the largest computing hardware facilities dedicated to life science research in Europe. In addition thirty science and IT businesses are located on the Norwich Research Park in the Norwich Bioincubator and the Innovation Centre.

b. Research strategy

Research in the School is predominantly applied, and is genuinely interdisciplinary: our collaborations include work with biologists, historians, insurance professionals and the medical profession. Over the REF period, our strategy of forging partnerships across the NRP and with industry has led to a rich research output as well as a diversification of funders and increased funding. Research awards totalled £13.5M in the REF period, of which £7.5M income is reported in REF4 (this compares with £6.4M income for RAE 2008). These awards are from a broad range of funders, including EPSRC, BBSRC, NHS, AHRC, NERC and the EU. The School also brought in over £1M from sales of spin-out companies, research contracts and consultancy payments. We have invested in new faculty to strengthen key research areas that underpin these collaborations: since RAE 2008, we have appointed a professor and a lecturer in computational statistics (Kulinskaya, largely funded by *Aviva,* and Nikoloulopoulos), two lecturers in computational biology (Greenman and Wu**),** and a lecturer in software engineering/machine-learning (Noppen).

Over the next five years our approach will be driven by the following goals:

- Maintaining RCUK funding whilst increasing the contribution of funding from commercial sources.
- Capitalising on the £15M NRP Enterprise Centre opening in 2014. This will provide new facilities for commercial activity undertaken at NRP. It will house new spin-out companies such as Finlayson's *Spectral Edge* and Theobald's *Moving Lips*, both of which exploit our research.
- Strengthening our links with NRP partners in the Biological and Environmental Sciences, in particular with The Genome Analysis Centre. We already have a joint lectureship based in this Centre (Greenman) and new joint fellowships are planned for the end of 2013.
- Extending collaborations with medical partners, in the Norwich Medical School and at the NNUH in the areas of data-mining, bioinformatics, graphics and imaging.
- Expanding our statistical research base in the insurance industry through our links with *Aviva plc.* and the Norwich Business School.
- Extending our current research collaborations (begun by Finlayson) with UEA's new School of Psychology in areas such as perception and multimedia synthesis and analysis.
- Increasing our industrial research base and developing our partnerships with key companies.

Research laboratories: strategy and achievements
In this section we introduce the three research laboratories, outline their strategy over the REF period, and document their resulting achievements.

Computational Biology (CB, led by Moulton): Biological sciences have changed almost out of recognition in the last two decades, with several of these changes being underpinned by advances in computational power and applications. In recognition of this, the CB lab, initiated in 2004, brings together roughly ten researchers. All are now housed in the custom-built D'Arcy Thompson Suite for Computational Biology which, as well as providing a suite of offices for researchers, houses a 3D printer, 3D visualisation devices and haptic devices. It was opened in 2008 and adjoins the School of Biological Sciences at UEA. Two substantial projects within the CB lab reflect the very different ways in which computing power can open up novel and incisive ways of "seeing" biological phenomena.

One of the major, and daunting, challenges in biology is to understand how patterns of differential gene expression arise and become translated into shapes. As observed by Turing in 1952, this phenomenon might be addressed by computer-based approaches. The recent work of Bangham and Kennaway, in a potent collaboration with Coen at the John Innes Centre, combines genetics, cell biology and mathematical modelling, and brings that prediction of sixty years ago to life. Their focus is on the ways in which flowers such as the snapdragon acquire their complex and predictable shapes. This story formed an exhibit at the London Science museum special exhibition on Turing (*Codebreakers*). Using a computational growth modelling software environment (*GFtbox*: http://www.uea.ac.uk/computing/software) a set of new techniques were developed, leading to several high profile publications in *Science*, *PLoS Biology* and elsewhere. These studies, initially funded by a £1.5M BBSRC grant, are continuing under the auspices of a €2.5M EU project with the John Innes Centre and now employing most of those involved in the initial studies. Other approaches to modelling growth, this time through cell division, were undertaken by Bangham in collaboration with Prusinkiewicz (Calgary)**.** Our 3D image interactive viewer (VolViewer http://cmpdartsvr3.cmp.uea.ac.uk/wiki/BanghamLab/index.php/VolViewer#Description) is now established as a component of the open microscopy environment, OMERO. This, in turn, sparked collaboration with Hayward and Laycock, resulting in haptic tools for exploring the steric interactions between enzymes and ligands (http://www.haptimol.com/). Hayward also developed new inverse kinematics tools (http://fizz.cmp.uea.ac.uk/dyndom/) to explore the remarkable topological features of the conformational space of protein loops—features known in robotics but hitherto unexplored in proteins.

A second major challenge posed by recent advances in biological sciences is the deluge of raw data produced by Next Generation Sequencing (NGS) technologies, which can deliver vast numbers (10^9) of short sequences (40–250 nucleotides) in short time-frames (hours). These require sophisticated analytical techniques to extract as much information, in as an effective way, as possible**.** This had already been anticipated by the appointments of Moulton and Huber and has been further strengthened in the REF period by an appointment that reflects the growing importance of our links within the NRP: thus, Greenman arrived in 2011 to a joint appointment between the School and TGAC. In 2010, we established a research facilitator post, funded equally by the Schools of Computing and Biological Sciences, to pump-prime new NGS-based collaborations and grants. During the REF period, and supported by two BBSRC grants, we developed widely used open-access algorithms and software for short RNA analysis (http://srna-workbench.cmp.uea.ac.uk) (Moulton). We also designed novel algorithms to estimate genome rearrangement histories in cancer (Greenman), and for analysis of molecular evolution (Huber, Wu).

Machine Learning and Statistics (led by Kulinskaya): The evidence base in health and social research and policy has been profoundly altered by the arrival of "big data". Data that was derived from specially-designed studies has been superseded by very large volumes of "real" data from a number of sources e.g. NHS, local government, businesses and social media. This massive increase in data has required new approaches to analysis, and we are using a combination of machine-learning and statistical techniques to exploit it. Work in kernel learning methods (Cawley), clustering, ensembles, multi-criteria data mining, and time series analysis (de la Iglesia, Bagnall) has been applied extensively.

With Toms (at the NNUH) we developed algorithms to predict hand shapes from radiographs, allowing paediatricians to produce fast and accurate estimates of bone-age (Bagnall). Further collaborations with researchers at the NNUH and the Norwich Medical School have enabled us to

show the power of data mining in routinely-collected health data. For example: to predict orthostatic hypotension with simple tests (de la Iglesia with Myint in the Norwich Medical School); to build accurate health risk models (de la Iglesia with Potter and others in the Norwich Medical School); and to build mineable clinical pathways for diseases such as prostate cancer (de la Iglesia with Donell and others at the NNUH).

Our work on model selection (Cawley) tackles the key problem of overfitting in machine-learning. We have developed a highly efficient model selection strategy based on virtual leave-one-out cross-validation whose performance is competitive with computationally expensive Bayesian approaches. This enabled Cawley to win the ICANN (Int. Conf. on Neural Networks) 2009 environmental toxicity prediction challenge.

We have further developed and extended our collaboration with *Aviva.* During the REF period, both the School and *Aviva* were interested in developing the area of applied statistical analysis, and this was reflected in two new appointments: Kulinskaya, to the *Aviva Chair in Statistics*, and Nikoloulopoulos. We have introduced fuzzy multiple comparisons procedures to solve the problem of multiple comparisons for discrete test statistics (Kulinskaya). This approach makes a theory of multiple comparisons, developed for continuously distributed statistics, automatically applicable to the discrete case. The importance of *copulas* (a type of probability distribution function) is recognised by the Basel II and III rules for banks and Solvency II for the insurance sector, which endorse the copula methodology as a unified tool for dependence analysis and risk management. Nikoloulopoulos has developed multivariate copula-based models and inference procedures for non-normal multivariate response data, such as financial assets. To date our work with *Aviva.* has been in both life and general insurance, and annuities. We are now exploring statistical analysis and mining of large patient databases from primary care sources to gain a better understanding of life expectancy.

Graphics, Vision and Speech (led by Cox): Audio and visual signals are rich and complex signals that are fascinating in their own right, and also for what they tell us about ourselves as humans. The graphics, vision and speech laboratory uses computational techniques to both understand these signals better, and to develop machines that have human-like capabilities.

The *Graphics Group*, led by Day, develops software for rapid generation of high-quality populated urban models, and for transforming those models into a form that is suitable for real-time rendered "walkthroughs" under user control. This work feeds directly into consultancy and industrial work via the School's consultancy company, *SYSCo*. For instance, Laycock's work has speeded up the process of visualising the locations of building footprints. This work was utilised in a KTP entitled HistOracle, which made Norwich heritage information publically available in an interactive platform. Lapeer collaborates with the NNUH and several companies (*Hexagon Metrology, Limbs & Things, Karl Storz Endoscopes, Michelson Diagnostics)* on medical research projects including augmented reality surgical navigation and surgical simulation and planning. Collaboration with plastic surgeons at the NNUH has yielded a reproducible methodology for simulating human skin for use in surgical simulators.

The work undertaken by the *Colour Group* exemplifies many of the desirable features that underpin our approach to research. Their work on the understanding of the human visual processes and development of computational theories for automated vision systems which replicate human visual abilities is innovative and original from a fundamental point of view. It has received substantial EPRSC funding and Finlayson himself has been a recipient of a Royal Society-Wolfson Research Merit Award since 2008. Furthermore, this research has been put into practice as the basis of two spin-out companies, *Imsense Ltd.* and the nascent *Spectral Edge Ltd*, and has a long list of industrial collaborators including *Apple, Xerox, Buhler-Sortex, Unilever* and *DataColor*. The School and University have invested substantially in the group by funding specialist darkroom facilities and staff. There are plans to make a further academic appointment in this field in 2016.

The *Speech Group*'s focus was previously on speech recognition, increasingly an established and commercial technology. During this REF period it has moved away from pure speech recognition towards the more ambitious goals of incorporation of visual information into several aspects of speech and audio processing. With funding from the EPSRC and Home Office, Cox, Theobald and Harvey have developed robust automatic lip-reading algorithms and demonstrated the first-ever

system that can identify language purely from lip-movements. Milner has also exploited visual speech information to improve traditionally audio-only methods of speech enhancement and speaker separation. Our growing expertise in joint audio/video processing was acknowledged in an EPSRC award to Cox to research the 'understanding' of events, using audio and visual information. In a long-standing collaboration with *Disney Research*, Theobald continues to develop better approaches for expressive avatar speech animation that allow for more efficient training and a wider range of expressions. The speech animation technology is actively supported by a UEA proof of concept award and a spin-out company (*Moving Lips*) will be formed to exploit the work commercially in the computer games and animated movie industries.

c. People

i. Staffing strategy and staff development

Responsibility for staffing strategy rests with the Head of School (Moulton) and the School's Executive Team (comprising six senior staff members). New appointments are aligned with the School's research priorities, as determined by the School's Research Committee, and new faculty are appointed only if they are judged to be producing research that is of internationally excellent quality. This committee, headed by the Research Director (Cox), comprises the lab leaders and the PGR Director. The Research Director also sits on the Faculty of Science Research Executive, which facilitates the flow of information between the School and the rest of the University, as well as ensuring that the School's strategy is informed by that of the University.

New members of staff have a mentor who is a senior member of their research lab. The School ensures that every new member of staff is given priority in the School's annual allocation of PhD studentships. New members of faculty at lecturer level are appointed with a probation period of five years, with the expectation that high quality journal publications are produced, and grant applications are made during this period. The School has a "workload model" which ensures that faculty engaged in research activities such as running grants and supervising PhD students have lower teaching and administrative duties. Credit is also given for enterprise and engagement activities such as developing technology, establishing spin-out companies and consultancy. The introduction of non-research contracts for a small number of faculty, who concentrate on teaching rather than research, has significantly freed up research time for the majority of faculty.

All staff have a formal annual appraisal. In addition, all research-active staff discuss annually their Research Plan with the Research Director and their lab leader, which ensures that the School supports faculty to develop their individual research. Furthermore, it allows the School to track research activity as well identifying new funding and collaborative opportunities.

The School actively encourages faculty to take study leave: faculty can apply for one year of study leave every seven years, or one semester of study leave every three years, on full pay. These periods allow for extended visits to corporate research labs of world-renown (e.g. *Apple*, *Disney Research* and *Hewlett Packard*) to Government labs (e.g. The Centre for Environment, Fisheries & Aquaculture Science) as well as globally-leading Universities. The School maintains a strategic fund that provides *ad hoc* funding for new initiatives that cannot be met from existing grants. During this REF period it provided £44K to staff from this fund.

Contract Research Staff: The Research Director is also the School's Research Staff Co-ordinator, providing information and advice to research staff regarding the support available to them from the University (e.g. Researchers' Working Group, Researchers' Fora etc.) and the School. All new contract research staff participate in a School-based induction programme. There is a CRS representative on the School Board. The CRS representative and CRS co-ordinator work together with faculty in the School, to ensure that all are aware of their contractual and Human Resources obligations to research staff. To support the implementation of the *Concordat to Support the Career Development of Researchers*, the University has established a Research Staff Working Group, chaired at pro-Vice Chancellor level and with School CRS co-ordinator membership. This steers the University's strategy for CRS career development and monitors the implementation of activities.

All appointments made by the School are governed by the University's equality and diversity regulations, which are overseen by a University committee and run by its Equality and Diversity

Office. In 2012, UEA was awarded a Bronze Award from Athena SWAN. The School has five female faculty, two recently appointed, and is working towards an individual Bronze Award.

ii. Research students

Research students play a vital role in our research, and during the REF period, we recruited no fewer than 87, the majority of whom held a first class degree and/or an excellent MSc. Students are funded from various sources, including EPSRC and BBSRC DTG funds; CASE-studentships; Norwich Research Park studentships; University and School scholarships; overseas government scholarships; and self-funding. The School was a partner in a successful application for one of 14 BBSRC Doctoral Training Partnerships awarded in 2012 jointly to the John Innes Centre and UEA. Our PGR recruitment process is rigorous, with potential students identified initially by application to advertised projects, followed by an interview with at least two faculty. Admissions decisions are made by at least two senior members of faculty and the Research Director and the student's academic ability is paramount. Funding is used strategically to (a) encourage research students into areas that are perceived as harder to recruit into; (b) to support new faculty; and (c) to address a particular requirement. The School's PGR Director (Huber) takes responsibility for overseeing both PGR recruitment and progress.

All PGR students have a primary supervisor who leads a supervisory team that comprises at least one other research active member of faculty. Faculty wishing to supervise a PGR student must undertake a University training course, and mentoring is provided for those new to supervision. Supervisory arrangements are set out by a Code of Practice, ratified by the University's Learning and Teaching Quality Committee. UEA adheres to the RCUK guidelines on PhD student supervision and training. The team has at least three formal progress meetings with the student during each academic year. The outcomes of the meetings are centrally reported, and evaluated by the PGR Director. Students intending to study for a PhD are initially registered for an MPhil and then "upgrade" after about 18 months. The upgrade process requires the student to give a twenty minute presentation on his or her research, as well as to submit a report that must include evidence of scholarly research, progress so far, and plans for completing the PhD.

All students register for a personal development plan, which is coordinated by the Faculty of Science Graduate School. These training programmes have been devised to comply with QAA guidelines and the Research Councils' Joint Skills Statement and consist of a combination of generic transferable and specific skills training. The School provides specialist courses (open to all PGR students in the University) on e.g. programming in different languages, NP-completeness and statistics. For their personal development plan, each student selects at least two weeks of training per year from a range of modules. These include oral and written communication, statistics, enterprise, engagement and impact, career development, and the social dimension of science. The programme is complemented by the School's annual Research Day, at which PGR students deliver either a short talk or a poster on their research. Students can intercalate from their studies to spend time working in industry: recently, three School students have had internships at *Apple*, one an internship at *Google*, and one spent six months at *Disney Research*. The School supports students with travel funds to attend and present talks at national and international conferences.

d. Income, infrastructure and facilities

Income

Research income over the six-year REF period was £7.5M, the main funders being EPSRC, BBSRC, NERC, UK central government bodies and the EU, with a significant contribution also from UK industry. For RAE 2008, we reported an income of £6.4M over a seven-year period, so the REF figure represents an approximate 35% increase over equivalent time periods. Future strategy is to grow our funding from commerce and industry and from central government sources to supplement Research Council funding. Some key grants in each lab are now highlighted below:

Computational Biology: Two BBSRC grants to Bangham totalling ~£1.7M represented 50% of a collaborative project with the John Innes Centre to understand the relationship between genes, growth and geometry in plants. Research in RNA silencing has greatly profited from new developments in sequencing technologies which can generate datasets containing millions of small RNA molecules. Moulton has obtained BBSRC funding in five grants totalling ~£2M to pioneer methods for bioinformatics analysis of small RNA next generation sequencing data together with

Dalmay in School of Biological Sciences and his colleagues. This has resulted in the UEA sRNA Workbench, a suite of tools for small RNA analysis, which is being developed through an ongoing BBSRC Bioinformatics and Biological Resources grant (£334K). In a recent NERC grant (£348K) Moulton is developing new bioinformatics techniques for metagenomics with Mock in the School of Environmental Sciences.

Machine Learning and Statistics: Machine Learning has been supported in part by two EPSRC grants: new classes of prediction problems (Cawley, £101K) and green computing (Bagnall, £91K). Additional external funding includes support from the Joint Information Systems Committee (JISC), from *Gardline Geosurvey*, and from the National Osteoporosis Society. Funding was also secured from *Aviva* (£300K) for the *Aviva Chair in Statistics*. Since her appointment to that post in March 2010, Kulinskaya has secured further funding of £200K from the company.

Graphics, Vision and Speech: During the period, Finlayson has obtained ~£1.5M funding from the EPSRC to support his work in colour image processing. Day's two EPSRC/SUSTRANS grants awarded in 2008 (total £477K) in which virtual urban visualisations and simulations are created, have led to the 'Historacle' Knowledge Transfer Partnership (£200K), a collaboration with the School of History at UEA and HEART (*Norwich Heritage, Economic & Regeneration Trust*). This has been the foundation for a recently awarded AHRC grant (£900K) with the School of History. Harvey, Cox and Theobald have developed techniques for machine lip-reading that are more independent of speaker, and the first ever system of language identification from visual information. This work was funded by an initial EPSRC grant (£391K) followed by a series of grants from the Home Office, Serious Organised Crime Agency and the FBI totalling £1.53M. This work was undertaken jointly with Surrey University, as was Cox's EPSRC-funded work on multi-modal understanding of (£366K).

Consultancies and professional services

Since 2000, the School has run its own consulting company, *SYSCo*, which makes the School's expertise available to industry, government agencies etc. Through *SYSCo* and *UEA Enterprises*, the School has also spun out companies, providing additional income for the School. More information about *SYSCo* can be found in the Impact Statement. Outside of *SYSCo* but through *UEA Enterprises*, separate long-term, consultancy contracts have been undertaken with *Aviva* (£150K) and a second large multinational company whose name is confidential (£150K).

Infrastructure and facilities

The School has a team of five specialist support staff, four of whom are graduates in computing science, whose duties include expert programming/debugging, support of specialist research hardware and planning and maintenance of the School's server infrastructure.

The following facilities and equipment are located within the School's 340m^2 of accommodation dedicated to research:

1. **Motion Capture Suite**: A set of eight infra-red cameras were provided by the BBC Research Department to provide facilities for high-resolution motion capture.
2. **Advanced graphics Suite**: 14 Dell precision high end workstations with specific video cards for graphics-related research are available. The lab is also used for games development and research using the Microsoft Kinnect and Xbox 360.
3. **Haptics Lab**: 12 Phantom Omni's and 1 Phantom Premium haptic force feedback devices used in conjunction with OpenHaptics software.
4. **Sound Room**: A specially constructed room with a range of audio and recording equipment including an acoustically isolated booth suitable for high-quality speech recordings.
5. **Colour Vision Research**: The dark room contains an extensive suite of specialised equipment including a spectraradiometer, a specially constructed high dynamic range display, controlled lighting and reference calibration targets. Psychophysical experiments are carried out in the group's visual assessment laboratory. This equipment implements the ISO standard for visual assessment (of photographic images). The labs were refurbished in 2010 at a cost of ~£35K.
6. **D'Arcy Thompson Suite**: The University invested £667K in 2008/9 in this facility which was formally opened in October 2008. The suite comprises 14 faculty/postdoc offices, two graduate laboratories, and a visualisation laboratory equipped with a 3D printer, a 3D projector and haptics equipment. These facilities were instrumental for Bangham's work on

3D growth of flowers. In addition, we invested in 8 Dell precision workstations each connected to Planar PX 2611W3D 3D screens and three high-spec servers (~£30K).
7. **Research and Visualisation Servers**: These are always the highest spec available, with top of the range processors, large hard disks and large amounts of memory. Equipment spend by the University in this area between 2008/09 and 2009/10 amounted to £725K.
8. **Macintosh Suite**: Following Cox's study-leave (2010) at *Apple* in California, *Apple* donated 14 high-performance Macintosh computers to the School. The School invested in the necessary building alterations to house them in a dedicated suite.

A centrally provided High Performance Computing (HPC) cluster is available to all researchers across UEA and is used extensively by all the School's research labs. The HPC cluster consists of 168 compute nodes providing 2016 processing cores each with 48GB–128GB of RAM and a total of 180TB of data storage across secure, scratch and on-demand tape storage. The University has invested a total of ~£3.5M in compute nodes and storage since 2008.

e. Collaboration or contribution to the discipline or research base

In this section, we provide highlights of the contributions of our faculty to the wider research base.

Collaboration
Collaborations with external academics are a key part of the School's research. For example, within UEA, Moulton together with Dalmay (School of Biological Sciences) have developed BBSRC-funded software for analysis of next-generation sequencing data, which has resulted in the discovery of short RNAs that regulate plant and animal development, including key crop plants such as tomato. At a national level, Harvey, Cox and Theobald have ongoing collaborative projects with Bowden (Surrey) (totalling >£500K from the Home Office, SOCA and FBI) investigating methods for automated lip-reading; whilst Finlayson works with Hurlbert (Institute of Neurosciences, Newcastle, (EPSRC, £800K)), Stockman (Institute of Optometry, UCL (EPSRC, £500K)) and Bloj (School of Life Sciences, University of Bradford, (EPSRC, £350K)) on different aspects of colour perception.

Internationally, notable examples of collaboration are: work by Laycock and Day with 18 European partners on the 3D-CoForm grant (£200K) building reconstructions of cities for cultural heritage; work by Finlayson and Anderson (a visiting researcher from Mediehøjskolen, Denmark, funded by an EPSRC grant) on camera calibration which won a best paper prize at the 5th *Colour in Graphics Imaging and Vision Conference*; and Huber and Wu's work with Steel (Canterbury, New Zealand) on analysing phylogenetic trees, supported in part with funding from the Royal Society. Hayward won a Furasato Award to fund a research visit to the laboratory of Kitao, Institute of Cellular and Molecular Biosciences, Tokyo, as part of a regular programme of visits.

Throughout the REF period, the School has maintained an active research seminar programme, augmented by seminars held by the individual labs. The School funds such seminars and also provides facilities, and some funding, to allow academic visitors to stay and carry out research within the School.

Industrial collaborations
The School maintains strong links with industry at many levels, from local SMEs to large multi-nationals. Links with multi-national companies include:

- *Apple* - Cox and Finlayson have both spent extended periods as visiting researchers or consultants at *Apple* headquarters in Cupertino, which has resulted in funding for a new laboratory and funded internships for three PhD students.
- *Aviva* - Kulinskaya works closely with *Aviva* which last year released further two-year funding for continuing support of the School's "Aviva Chair".
- *Disney Research* - Theobald is a regular, fully funded, visitor to *Disney*. His PhD student, Taylor, spent two extended periods at *Disney Research* before joining the company as a researcher.

Other companies with whom the School regularly works include *Buhler Sortex, Xerox*, *Datacolor* and *Unilever.* Some of our collaborations have been supported by RCUK-funded schemes that encourage such activities. For example, Cox and Bagnall received EPSRC awards to work with two local companies: *Green Energy Options* via a CASE award for software for smart energy

meter; and *ei Technologies* via a Technology Strategy Board award to develop a smartphone application to detect emotion in speech.

Interdisciplinary research

Much of the School's research is genuinely interdisciplinary. For example:

- Bangham and Coen (at the John Innes Centre) have received over £3M from BBSRC to develop computational models of plant growth which integrate computational inputs, based on sophisticated genetic and cell biological analysis of flower development.
- Experimental and behavioural psychologists at the Universities of Virginia and Pittsburgh are key collaborators for Theobald, allowing him to engage in better understanding of behaviour in conversation using facial image synthesis techniques.
- Day and the School of History at UEA have a £900K AHRC grant to bring Magna Carta to life, with Oxford, Exeter, Kings College and the British Library also participating.
- Nikoloulopoulos has worked extensively with Joe (British Columbia) and Li (Washington State) with copula dependence modelling for multivariate data with applications in finance and health sciences.
- In collaboration with plastic surgeon Vasu Karri (Guys Hospital, London), Lapeer has developed haptic software to teach inguinal hernia repair to trainee surgeons.

Examples of leadership in the academic community

- Finlayson was elected Fellow of the Society of Imaging Science and Technology (2010), holds a Royal Society-Wolfson merit award (2008), and was awarded the Davis Medal by the Royal Photographic Society (RPS) in 2009 for outstanding contributions to the photographic industry. He was made a Fellow of the Institution of Engineering and Technology (IET) in 2013 and a Fellow of the RPS in 2012.
- Kulinskaya was elected a member of the International Statistical Institute in 2010 and a member of the Society for Research Synthesis Methodology in 2012. She also chairs the Statistical Methods Group of the Collaboration for Environmental Evidence (CEE).
- Lapeer and Finlayson are members of the EPSRC College and, together with Cox**,** have served on EPSRC panels.
- Day is a Fellow of the European Association for Computer Graphics.

Examples of conference organisation

- Theobald and Harvey were co-chairs of the International Conference on Auditory-Visual Speech Processing (AVSP) 2009 and Theobald was co-organiser of the LIPS2008 and LIPS2009 visual speech synthesis challenges, which ran as special sessions at Interspeech 2008 and AVSP 2009 respectively.
- Moulton was principal organiser for a one-week conference on phylogenetics at the Isaac Newton Institute for Mathematical Sciences in June 2011.
- Cox was Technical Chair of Interspeech 2009, attended by ~1100 delegates.

Examples of keynote speeches

- Laycock and Hayward: Virtual Reality and Drug Design Workshop 2011.
- Cawley: plenary speaker at Intelligent Data Analysis (IDA) 2012, Helsinki, Finland.
- Moulton: keynote speaker at ALGO 2011, Saarbrucken, Germany.
- Nikoloulopoulos: invited speaker at the Workshop on Non-Gaussian Multivariate Statistical Models and their Applications, Banff International Research Station, Canada, 2013.

Examples of editorships

- Moulton: associate Editor of *IEEE Transactions on Computational Biology and Bioinformatics*.
- Finlayson: associate editor for *IEEE Transactions on Pattern Analysis and Machine Intelligence*.
- Day: associate editor of *Computers and Graphics International* and an editor of *International Journal of Heritage in the Digital Era.*
- Laycock: Associate Editor of the Elsevier *Journal of Graphical Models*
- Kulinskaya: Editorial Boards of *Research Synthesis Methods* and *Environmental Evidence*.