Environment template (REF5)

Institution: Manchester Metropolitan University
Unit of Assessment: B11 Computer Sciences and Informatics
a. Overview Computing and Informatics Research at Manchester Metropolitan University (CIR@MMU) is situated within the Dalton Research Institute (DRI) in the Faculty of Science and Engineering. Members are all affiliated with the School of Computing, Mathematics and Digital Technology (SCMDT). The Unit is organized according to three main research groupings: Biological and Sensory Computation (Leader: Martyn Amos; plus Costen, Li and Yap), Computational Intelligence and Reasoning (Keeley Crockett and Vladimir Rybakov; plus Latham and O'Shea), and Networks and Distributed Systems (Liangxiu Han; plus Hammoudeh and Muyeba). Researchers in all three groups work closely with colleagues in other Units; in particular, with those in UOA A3: Allied Health Professions. Our very best, leading-edge research derives from national and international collaborations in synthetic biology, image analysis in human physiology, conversational agents for intelligent tutoring and gene expression analysis. These are all areas with high growth potential, and we are well placed to apply our core computer science expertise to future problems.

b. Research strategy

CIR@MMU is characterised by its distinctive mix of expertise, research strengths and interdisciplinary activities. We combine top-quality foundational work with a portfolio of threads that reach out to make significant contributions at interdisciplinary boundaries. An over-arching theme of our research is biomedical science and healthcare, and this area is now a key research priority of the University. Our vision is to become a leading hub for fundamental and applied research at the interfaces of computer science, biomedical science and healthcare, specialising in transformational innovations at these boundaries that could underpin long-term developments both across and outside our focus application areas.

2008-2013 strategy. The key aspects of our post-2008 strategy were (1) collaboration, (2) profile, and (3) mentoring and staff development. For (1), we aimed to encourage and develop research interactions (a) within CIR@MMU, (b) between CIR@MMU researchers and other units within MMU, and (c) beyond MMU (including participation in EU-funded research projects). For (2) we sought to both increase research volume (partly through an increase in the number of Ph.D. students supervised), and to improve the international profile of our research outputs by targeting higher quality journals and respected conferences. To address (3), we restructured the organization of research within CIR@MMU, and worked to ensure internal promotions would improve the overall research environment. We now describe key strategic achievements post-2008.

1. Collaboration. In the last assessment period CIR@MMU has moved to a much more "outward-facing" model of research collaboration, helped, in part, by the EPSRC-funded Bridging the Gaps: NanoInfoBio project (NIB) (EPSRC: EP/H000291/1) held by Amos, which operated from 2009 to 2011 (and which forms the basis of one of our impact case studies). The aim of this project was to encourage interdisciplinary research within MMU, by both building and strengthening connections between computer science, chemistry, biology, engineering, mathematics, and healthcare science. This created several new and significant collaborations between CIR@MMU and healthcare science, and other projects have also subsequently emerged. The strategic decision to appoint at the healthcare/informatics intersection (Han) has proved to be successful, with £210,00 of funding gained over two grants (BBSRC: BB/K004077/1; EPSRC: EP/J50063X/1). Han currently collaborates with the MRC, and the Universities of Edinburgh and Aberdeen on three biomedical-based projects. We have also been particularly successful in attracting project support from the European Commission (EC), and this funding source is central to our future research strategy. We are very well-represented in the EC Future and Emerging Technologies (FET) programme; in RAE2008 we were unable to report any funding at all from the EC, but in the REF reporting period we obtained three FET grants (BACTOCOM (248919), COBRA (270371) and TRUCE (318235); PI: Amos), totalling £2.6M. This significant growth in EC funding underpins our strategic commitment to supporting interdisciplinary work at the intersection of computer science/biology.

2. Profile. Between January 2008 and November 2013, returned staff produced 89 refereed journal papers, 141 refereed conference papers, and 8 book chapters. Since REF2008, this represents a shift in publishing focus away from conference papers and co-edited books, and towards high-quality journals. In order to aid dissemination of our results, we have encouraged submission to highly rated open access journals (e.g., PLOS ONE, BMC Systems Biology), supporting page charges from School funds. Since 2008 we have conferred 16 Ph.D. degrees, which represents a >200% increase on RAE 2008. This has allowed us to significantly ramp up the overall level of research activity. High profile results emerging from CIR@MMU in the period 2008-2013 include the award of a Dorothy Hodgkin Postgraduate Award to support work on the detection of eye disease (the first such award to a new University), our research-driven public engagement work being featured on the *BBC 10 O'clock News*, and one of our Ph.D. students finishing as a runner-up in the 2012 BCS Machine Intelligence competition.

3. Mentoring and staff development. Since RAE2008 we have restructured the unit in order to both focus on areas of strategic importance and to ensure that researchers receive the best possible support from senior staff. We have moved from five research groups to three; this involved merging the Novel Computation and Image and Sensory Computation groups (to form the new grouping of Biological and Sensory Computation), as well as the Logic and Computation and Intelligent Systems groups (to form the new Computational Intelligence and Reasoning group). In addition, since RAE2008 we have added a new Networks and Distributed Systems group; this was a result of the strategic appointment of Liangxiu Han from the University of Edinburgh, and allowed us to integrate several other new appointments (Muyeba, Hammoudeh) into a rapidly growing group that has already achieved significant success in terms of grants and publications. In the current period, all three groupings have attracted at least two external grants. In recognition of our developing profile, CIR@MMU has received significant support in terms of both new appointments and internal promotions. Of the twelve individuals returned, five (Latham, Han, Muyeba, Hammoudeh and Yap) were appointed since the 2008 REF. One of these (Han) is now a research group leader (Networks and Distributed Systems), and she was promoted to Reader in 2012. Of the individuals also returned by us in the 2008 RAE, Amos was promoted to Reader in 2010, and to Professor in 2012, and he now has overall responsibility for CIR@MMU research. Costen was promoted to Reader in 2011, and Crockett was promoted to Reader in 2012. Crockett now leads the Computational Intelligence and Reasoning group. As such, all research groups are now lead by either Professors or Readers, which was not the case in 2008. Two group leaders (Amos and Han) are now members of the EPSRC Peer Review College; we had no members to report in RAE2008.

Vision. CIR@MMU combines high quality foundational research with world-leading interdisciplinary contributions, particularly at the life sciences interface. Our specific strengths build on world-leading work on unconventional computation, image/data analysis and computational reasoning. As a discipline, computer science increasingly lies at the heart of important scientific developments, and we have successfully positioned ourselves to make significant contributions in a small number of high-impact, interdisciplinary areas.

Research strategy. From 2013, the way in which we structure, manage and communicate research within CIR@MMU will better reflect our core strengths, rather than reflecting historical situations. In terms of the research culture in CIR@MMU, we have identified the following four areas for further development:

1. Cohesion and communication. Strongly supported by the School, Faculty and University, we have broad aims to intensify research in CIR@MMU by supporting our staff to develop exciting research proposals, and supporting staff research ambitions by increasing the numbers of research students by a variety of means. One of the key strategic initiatives we have operated to achieve these ambitions is to reconfigure our research grouping strategy. The plan targets a move away from conventional research groups towards innovative translational research themes (described below), which reflect the broader challenges being encountered at local, national and international levels. By allowing staff to work together on key problems, we will dissolve artificial barriers between groupings, and encourage new collaborations (this is already beginning to happen, for example, between Computational Intelligence and Reasoning and Networks and

Distributed Systems). Research within CIR@MMU will be actively managed in a coordinated fashion by a group of senior researchers (Amos/Costen/Han/Crockett/Rybakov), who will work to ensure optimum levels of communication, cross-fertilisation and resource sharing between groupings.

2. Key themes. The research areas that we will develop draw on existing strengths within CIR@MMU, and are aligned with the strategic plans of funders such as the European Commission and the Research Councils. We specifically target the European Horizon 2020 Societal Challenges of "Health, demographic change and wellbeing" and "Inclusive, innovative and secure societies" (the latter via our growing focus on security, via links with colleagues in Engineering). In focussing on these areas, we will take advantage of natural local synergies with members of the Allied Health Professions UoA at MMU, with whom we now regularly collaborate. Members of CIR@MMU are also leaders in "future and emerging technologies" (FET, as defined by the European Commission), where different scientific disciplines converge to facilitate the development of speculative, high-risk research. We will seek to further strengthen this position, as FET forms a central (and growing) component of the Horizon 2020 Excellent Science agenda. We will increase both our support from - and influence over - the FET programme, via new grants and continued involvement in consultations with the Commission. The Unit is also well aligned with the EPSRC Delivery Plan, and we will specifically target areas (in which we have current capability) that are flagged for growth, such as synthetic biology, digital signal processing, and energy efficiency. The Research Council grants we have obtained in the REF period cover priority topics such as artificial intelligence, video analysis, gene annotation and the detection of disease. We will, therefore, continue to build on this strong, well-established foundation.

3. Facilitation. The most obvious route towards facilitating research is external funding, and we will aim to significantly increase the number of high-quality proposals we submit. By (1) sharing best practice (including successful bid documents), (2) helping staff to identify potential sources of funding (with the support of a recently expanded Research and Knowledge Exchange office); and (3) financially supporting staff to attend research networking and proposal development meetings, we expect to see a further growth in our levels of support. After external funding, the most significant factor in our post-2008 success was the increase in Ph.D. student numbers, with an accompanying rise in research productivity. By emphasising interdisciplinarity and undertaking co-supervision across Schools, we will continue our success in competing for centrally allocated Ph.D. studentships and resources. The EPSRC-funded NanoInfoBio (NIB) project allocated three project grants/Ph.D. studentships to SCMDT, two of which (GPUs and muscle analysis, and age-related decline in musculoskeletal function) have directly led to strong, sustained and internationally excellent collaboration between Costen and colleagues in Healthcare Sciences. As the MMU internal model places increasing emphasis on targeted, cross-Faculty collaboration for postgraduate research and seed-corn funding, we are ideally placed to take advantage of this policy. In addition, a new University policy will ensure that the majority of overheads on funded grants are returned to researchers, ensuring that this money can be reinvested in research.

4. Public engagement and impact. We also acknowledge the importance of public outreach and engagement, both ideologically and practically. Public engagement is fundamental to the development of trust and understanding between scientists/engineers and the wider community, and much of our work concerns areas with significant underlying legal, ethical and social issues. By continuing to expand our work in this area (e.g., by encouraging postgraduate students to register as STEM Ambassadors, developing activities for the Manchester Science Festival, giving talks in schools and writing popular science articles and books) we will further strengthen the reputation of computing at MMU as a leader in public engagement (underlined, for example, by the CIR@MMU-led DIYBIOMCR project (which forms the basis of one of our impact case studies) receiving a Manchester Beacon Award).

c. People, including:

1. Staffing strategy and staff development

To support the strategic aims of CIR@MMU, the following new policies and initiatives are now in place: (1) ensuring, where possible, support for new appointments and internal promotions in areas of strategic importance (such as the informatics/healthcare interface, security, and future and emerging technologies), (2) maximising staff research development opportunities by leveraging School funds with matching funds from other sources to increase the number of Ph.D. studentships available, (3) providing (via the senior staff group) active mentoring to staff at all career stages, including the provision of editorial input on draft papers and funding bids, advice on research supervision, and insights into career development, and (4) ensuring that research active staff have ample resources to pursue their ideas (e.g., through small "bootstrapping" funding allocations from QR funds, or from support via Knowledge Transfer Partnerships (KTPs) and other mechanisms such as the Knowledge Exchange and Innovation Fund (KEIF) and annual Ph.D. studentship competitions).

In the current period we have operated, with top priority, a strategy to protect research and knowledge exchange time for our staff. Via agile streamlining of administration of teaching loads, and the appointment of additional teaching support tutors, non-timetabled staff time has been ring-fenced (that is, we have been able to maintain levels of allocated research/KE time). This strategy will continue for the foreseeable future. With other units, CIR@MMU enjoys central support from the University, one form being the Research Accelerator grant scheme. This is targeted at ECRs, and offers pump-priming support designed to cover costs of research, and to help younger researchers develop the skills and confidence to apply for external funding. One of our academics (Yap) currently holds such an award. MMU academics also participate in KTPs; a recent example involved our staff working with Tyrell Systems on "remote control" of buildings, via an iPhone app. Another hugely successful app that we have developed is the Manchester Time Machine, the first ever app for the iPhone to merge archive film with GPS, and which offers a street level tour of Manchester's streets and people over the last 100 years.

The University's commitment to staff was recently evidenced by our gaining an Investors in People "Gold" Award. MMU is the largest of only five Universities to receive such an award, which places us in the top 1.5% of organizations in the country. The University has also recently received the Athena SWAN Bronze Award, which acknowledges the positive and tangible action being taken by the institution to advance the representation of women in science, engineering and technology. Of the 12 individuals returned in our UoA, 5 (42%) are female, and two out of three research groups are led by women. The proportion of women in the CIR@MMU is well above the sector average of 21.7% for IT and systems sciences, and computer software engineering[1]. Crockett currently chairs the IEEE Women in Computational Intelligence Group, of which Latham is also a member. Both are also members of the IEEE Women in Engineering Society (Crockett as a Senior Member).

The University's commitment to equal opportunities is set out in MMU's Equality and Diversity Policy, Vision for Equality and Diversity and Single Equality Scheme. These policies, along with the Equality Act 2010, guide and inform our approach to supporting the Research environment within MMU. All support processes and structures for research comply with the principles of the 'Concordat for the Career Development of Researchers' and MMU has been awarded the EU HR Excellence in Research Award in recognition of the quality of these processes.

2. Research students

We have more than tripled our number of doctoral conferrals (from 5 in RAE2008 to 16 in this period). In addition to our policy of attracting the best Ph.D. students from outside the institution, supported by funded studentships, we also emphasise the importance of nurturing our own talent from within. We achieve this both by identifying and encouraging promising undergraduates for

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[1] HESA breakdown of academic staff by gender, 2011/12.

possible research careers, and by ensuring that existing research students can flourish and develop into members of academic staff. Examples of successful outcomes of these policies include the previously-mentioned shortlisting of a Ph.D. student for the final of the 2012 BCS Machine Intelligence competition (supervised by Crockett and O'Shea), the 2013 shortlisting of an undergraduate project for the BCS Project Prize (supervised by Crockett), the presentation of three undergraduate projects as papers at the 2012 International Conference on Cybercrime, Security and Digital Forensics (supervised by Han and others), and the participation of several of our Ph.D. students in ground-breaking public engagement activities (such as the 2013 award-winning *Deadinburgh* experiential theatre production, to which we contributed scientific expertise: see http://www.bbsrc.ac.uk/web/FILES/Resources/deadinburgh-events-programme.pdf).

The University student development programme ensures that postgraduate researchers have the skills and confidence to successfully manage their research career. This programme provides support that complements the specific training offered in Faculties. A full induction process ensures that students are integrated into the School at the earliest opportunity, and that their progress is regularly monitored. The MMU Postgraduate Passport is geared towards students who are close to the end of their research programme, and is geared towards employability. A QAA audit in 2010 praised MMU's "good practice…contributing to the academic standards and the quality of learning opportunities in the…comprehensive training and development opportunities provided for postgraduate research students."

All students are provided with a desk in dedicated office accommodation, along with IT facilities, and labs are themed wherever possible, in order to ensure cohesion and ease of communication. All students have at least two academic supervisors, and detailed records are kept of supervision meetings (this process being overseen at the Faculty level). Each student has a formal annual review of progress, which is performed by an independent reviewer. In addition to the year-long student development programme, students participate in an annual postgraduate student conference at the University, at which they have the opportunity to present a poster and network with colleagues. Students have access to School travel support in the form of at least one non-UK conference trip during a standard Ph.D. The opportunity to gain teaching experience is also available through Teaching Assistantships, and several of our students are active public engagement STEM Ambassadors.

d. Income, infrastructure and facilities

The School has enjoyed a significant growth in external income. In the current period, we were awarded 14 significant grants, with income from all sources totalling £3.53M (including £1.4M specifically for spend at MMU). This MMU income represents a 129% increase over RAE2008. The table below lists our main awards in this period, shows how it is distributed over our main research groupings, and also indicates relative performance in these areas since RAE2008. Our main awards were distributed over funding sources as follows: UK Research Councils (58%), EU (27%), KTPs (11%), charities (3%), professional bodies (1%). For reference, in RAE2008 we returned a total of £610,508 (£164K of Research Council funding, £345K of EU funding, and £100K from other sources). In terms of investment in infrastructure, the University has provided the School with a state-of-the-art Usability Laboratory (cost: £150K). This facility, unique in the North West, is designed to capture and analyse human behaviour during interaction with a host of technological devices including computers, mobile devices and video game consoles. The Faculty has also supported research activities within the School, through the provision of a high-performance computing cluster. Research activity is based in recently refurbished office accommodation, which includes a common space for informal meetings. One administrator and one project manager are supported by external research funding, in addition to central administrative support provided by the University. We also have access to the expertise and support offered by the Research and Knowledge Exchange (RKE) office, who provide regular training opportunities in grant writing, knowledge transfer and ethics and governance issues. The RKE office also provides a staff development programme, and manages the University research infrastructure and Ph.D. processes. MMU libraries offer excellent provision, including electronic and physical access to all academic libraries in Manchester.

Grant	Funder	MMU amount	Research area
NIB	EPSRC	£289,095	All research areas
Video face rec.	EPSRC	£71,673	Biological & Sensory Computation
Hybrid systems	EPSRC	£23,715	Biological & Sensory Computation
BACTOCOM	EU FP7	£258,856	Biological & Sensory Computation
COBRA	EU FP7	£81,918	Biological & Sensory Computation
TRUCE	EU FP7	£46,610	Biological & Sensory Computation
DIYBIOMCR	Wellcome	£29,705	Biological & Sensory Computation
Logics of AI	EPSRC	£255,488	Computational Intelligence & Reasoning
Clinical trials	FHI	£13,701	Computational Intelligence & Reasoning
Ind. Placement	RAEng	£15,145	Computational Intelligence & Reasoning
AGILE	BBSRC	£120,000	Networks & Distributed Systems
DHPA	EPSRC	£90,000	Networks & Distributed Systems
KTPs (x2)	Momenta	£160,517	Knowledge Exchange

Full details of all grants are at http://www.scmdt.mmu.ac.uk/cir/REF

The institution is committed to the principles of Open Access. The School has made a significant amount of money (£25K) available to researchers in the form of a REF development fund, and a large proportion of this has been used to support gold publication in high-ranking open access journals (e.g., PLOS ONE).

The University has recently agreed that external funding overheads should be returned to researchers, wherever possible. Science and Engineering is the Faculty that generates the most research income within the University, and CIR@MMU income has grown significantly in the REF period. As a result, we will return *at least* £50K to CIR@MMU researchers in 2013/2014, and around £70K in 2014/15. Over both periods, this will be allocated as follows: £35K to staffing (e.g., to employ associate lecturers in order to relieve research active staff of teaching, bridging funding for RAs between projects), £50K travel and subsistence (e.g., to support attendance at high-quality conferences, and to foster strategic collaborative bids), £30K to equipment to support strategic research areas (e.g., GPU machines), and £5K for consumables (e.g., software licences).

e. Collaboration and contribution to the discipline or research base

1. Collaborations

Amos coordinated the European BACTOCOM research project, which had partners in France, Spain and Germany, as well as advisors from the UK, USA and Sweden. He currently runs two European coordination actions, which are specifically intended to help to develop and direct the research base in Europe and beyond. The first, COBRA, is dedicated to biological and chemical information technologies, and has partners in Denmark, Germany and Italy. The second, TRUCE, aims to develop research and training in unconventional computation, and brings in partners from the UK, Denmark and Spain. The BBSRC-funded AGILE project (Han, PI) is being undertaken in collaboration with colleagues at the Medical Research Council Human Genetics Unit at the University of Edinburgh. Han also collaborates with the University of Aberdeen on a TENOVUS Scotland-funded project on the mathematical understanding of obesity and type 2 diabetes, and with the University of Edinburgh on an Amazon-funded project on large-scale gene expression pattern annotation in mouse embryo images. Costen has recently commenced a University-funded collaboration with Warwick Medical School to characterize and model the changes in cells seen in pre-implantation human blastomeres. Li collaborates on MRI and ultrasound image analysis with the MMU School of Healthcare Science and the Indian Institute of Technology, and on medical image processing for Notch signalling, with the University of Manchester. Pilot work by Crockett and O'Shea was funded as part of a larger project by international collaborators, Family Health

International (USA), to investigate the classification of comprehension / non-comprehension on the part of Tanzanian women participants in field studies on the prevention of HIV infection.

2. Exemplars of interdisciplinary research

Many of the projects already mentioned are inherently inter-disciplinary, as they involve researchers from computer science, biology, bioinformatics, engineering, and several other disciplines. Academics from CIR@MMU also co-supervise Ph.D. students with colleagues outside the unit: for example, Amos co-supervises two students with Art and Design (computational architecture and generative processes for fabric printing), and Costen has students supervised jointly with Health Sciences and Engineering, looking at aspects of muscle and joint modeling. Within the broader context of MMU, members of the School have been instrumental in setting up many brand new interdisciplinary collaborations, often via the NanoInfoBio project.

3. Collaborations with research users

In terms of industrial research collaboration, recent projects include a study of automatic crush detection in crowds, undertaken as a Ph.D. by an MMU graduate, and co-supervised by Amos and a colleague from Hughes Associates, Inc, Current commercially-informed Ph.D. projects include real-time muscle activity interpretation from ultra-sound (supervised by Costen, in conjunction with Vicon Ltd), fast extraction of Facial Action Coding parameters (Costen and Yap, in association with Paul Ekman International plc.), tele-rehabilitation, funded by KEIF, and conducted in collaboration with the NHS Lothian Telehealth and Telecare Board, and Consard, Ltd. (Li), and automatic extraction of glaucomoa features using digital retinal images, with Optos PLC, Ltd. (Li).

4. Exemplars of leadership in the academic community

Amos and Han both serve as members of the EPSRC Peer Review College. Amos is the Series Editor of the Synthesis Lectures on Synthetic Biology (Morgan and Claypool), an Associate Editor of the International Journal of Natural Computing Research, and a Member of the Editorial Boards of the International Journal of Natural Computing Research and the International Journal of Unconventional Computation. In the REF period he served on the program committee (PC) of the Congress on Evolutionary Computation (2009), the 12, 13th and 14th Artificial Life conferences (2010, 2012, 2014), and the IEEE Fifth International Conference on Bio-Inspired Computing: Theories and Applications (BIC-TA 2010). Amos served as a founding director of ArcSpace Manchester, a social enterprise partnership, which developed from his role as a University Public Engagement Fellow. He also coordinated the Wellcome Trust-funded "Manchester DIYbio" public outreach project, which is now a stand-alone organization. Han currently holds a Higher Education Academy grant on improving student learning in security and computer forensics (BLOSSOM project, http://journals.heacademy.ac.uk/doi/full/10.11120/ital.2013.00006). PC: ZEMCH (2012), International Conference on Advanced Engineering Computing and Applications in Science (2009, 2010), CLOUD Computing (2010). Costen serves on the editorial board of the American Journal of Signal Processing. Crockett chairs the IEEE Women in Computational Intelligence Society Committee, is a co-organiser of the IEEE Symposium on Computational Intelligence in Industry (CCI 2013, Singapore), served as technical co-chair for IEEE Fuzzy Systems (as part of the IEEE World Congress on Computational Intelligence, 2012), was an IEEE Travel Grants administrator (annual budget of $100K) and a member of the CIS Awards Sub-committee on Industry Liaison. She was the joint programme chair and organizer of the IEEE WCCI Workshop on Applications of Computational Intelligence to Benefit Society (2008), the technical co-chair for IEEE Fuzzy Systems at WCCI 2012, and co-organizer of KES-AMSTA 2011 O'Shea served as the General Chair for KES-AMSTA 2011. He is a member of the Editorial Board of the International Journal of Intelligent Defence Support Systems, and an Associate Editor of the International Journal of Knowledge-Based and Intelligent Engineering Systems. PC: KES-AMSTA, and KES International Conference on Intelligent Interactive Multimedia Systems and Services. Rybakov was the co-chair of the PC for the UNIF workshop, held as part of the Turing Conference IJCAR (2012).