

Institution: Sheffield Hallam University
Unit of Assessment: UOA11 - Computer Science and Informatics
1. Unit context and structure, research and impact strategy Context and Structure Research in this Unit addresses the University's Transforming Lives strategy through the development and application of computer science and informatics approaches to solve real world issues and societal challenges. Research is undertaken in partnership with businesses, health organisations and security organisations across the region, nationally and internationally, and falls broadly within the ACM classification of Applied Computing. This is Sheffield Hallam University's first submission to Unit 11, with a staff base comprised of 27 (25.6 FTE) which has been developed through this period. In REF 2014, three staff in this submission were submitted to <i>Communication, Cultural and Media Studies, Library and Information Management</i> (Andrews, Dearden, Rodrigues) and one to <i>Electrical and Electronic Engineering, Metallurgy and Materials</i> (Alboul). From this small research base, with targeted investment and a strategy for growth through recruitment and staff development, the University's capacity and capability in computing research has grown significantly to underpin this new Unit. Submitting to UoA11 has meant that a number of staff outside the core Department of Computing have also found a more appropriate Unit for their research, with the inclusion of six staff from the Department of Engineering and Mathematics (Faust, Pranggono, Rodrigues, Saatchi, Shenfield, Sherkat), two from the Materials and Engineering Research Institute (Alboul, Conti), and one from the Centre for Excellence in Terrorism, Resilience, Intelligence and Organised Crime (Gibson). Research Strategy The strategy over the assessment period has been to establish, develop and grow the Unit as a focus of support for staff across the University whose research specialisms coalesce around the broad theme of Applied Computing. Support for Computing researchers, and the development of a standalone Unit 11 was, for most of the census period, located in the interdisciplinary <i>Cultural, Communication and Computing Research Institute (C3RI)</i>. 2020 saw a major restructuring at Sheffield Hallam, with the formation of four new research institutes, including the <i>Industry and Innovation Research Institute (I2RI)</i>, to which the Department of Computing and Unit 11 is aligned. Since 2014, the University has been committed to growing research in computer science as a strategic priority. Investment has been targeted at developing staff and infrastructure through the allocation of research time, new staff recruitment, funding of specialist facilities, pump-priming project funding, and support for dissemination activities. This investment has advanced outputs, external grant capture and the impact of our work. As part of this strategy, a <i>Computing Research Committee (CRC)</i> was created in the Department of Computing in 2016 and Andrews was appointed as a dedicated Department Research Lead. The CRC initiated a process of supporting the development of individual staff research plans as part of the annual work-planning and professional development process, and making recommendations for the allocation of additional research time for each member of staff. Through this approach, the CRC was able to identify and support core areas of excellence, such as: conceptual structures, semantic technologies, pattern recognition, robotics and AI, sensors and ad-hoc networks, IoT and VR games. Based on the strategic planning of the CRC, the Department supported the formation and expansion of research groups in these areas to underpin the growth of research across the broad theme of Applied Computing. The Department also targeted additional research time to specifically support high impact research (Andrews, Dearden, Roast), support the development of ECRs (Ajao, Davies, Enamamu, Otebolaku, Wang), and support

staff to undertake PhDs. Over the period this resulted in the equivalent of 6 FTEs of additional research time being allocated to staff in the in 2019/20 compared to less than 1 FTE in 2014/15. During the period, the staff recruitment strategy of the Department also changed, with a much greater emphasis being put on recruiting staff with strong research track-records aligned to the research specialisms (e.g. **Di Nuovo**, **Da Costa**, and **Marchang**).

Engagement and Impact

Oversight of the strategy and its implementation to grow research with impact is predominantly delivered through the Departmental Research Lead and CRC, and via the dedicated research groups and areas of specialism, as detailed below.

Research Groups

The **Conceptual Structures Research Group (CSRG)**, led by **Andrews** and **Polovina**, is innovating in semantic technologies and knowledge representation and reasoning. **Andrews'** interest is in Formal Concept Analysis and new ways of computing formal concepts faster, demonstrated in [10.1016/j.ins.2014.10.011](#) and [10.1007/978-3-319-59271-8_4](#). 'In-Close' was adapted in the €3.5m EU ePOOLICE project (Grant ID: 312651, returned under UoA34) to provide corroborated evidence of organised crime and in the €2.6m EU ATHENA project (313220, UoA34) to cluster reports of incidents for crisis management. **Polovina** investigates how Conceptual Graphs and ontologies can provide richer models of enterprise architecture to improve business processes: [10.3233/ao-180198](#). **Hirsch** explores how genetic algorithms can be used for document analysis to provide results that are semantically richer than existing approaches: [10.1109/CEC.2017.7969447](#). **Roast** is interested in how visualisations can be used to assist users in creating spreadsheet formulae, and **Gibson** has been exploring how adjacency matrices can be used to visualise larger 'small-world' networks: [10.1016/j.asoc.2016.01.036](#).

Interdisciplinary research involving the CSRG increased significantly with the creation of the Centre of Excellence for Terrorism, Resilience, Intelligence and Organised Crime Research (**CENTRIC**). The Centre was founded in 2011 by Akhgar (Director of CENTRIC, UoA34), with **Andrews**, and has provided a rich forum for combining research in social media, smart devices, semantic technologies, visualisation and communication. This interdisciplinary activity has led to two of the Unit's Impact Case Studies (ICS1 and ICS2) and is evidenced in two key papers: [10.1186/s13388-018-0032-8](#) and [10.1007/s10844-016-0404-9](#). These works had a significant contribution in securing the €5.0m European TENSOR project (700024, returned against PI Akhgar in UoA34), identifying and analysing terrorist generated content on the Internet and Dark Web.

The **Smart Interactive Technologies Research Group (SITRG)**, led by **Di Nuovo**, focuses on identifying and applying novel computational models of systems that socially interact with and empower human beings. **Di Nuovo** has explored theories of number learning in children and developing a new mental neurorobotics model of number understanding, and **Conti** is interested in improving the human acceptance of robots in education and social care settings. Their pioneering work involves multidisciplinary teams with expertise in cognitive science, robotics and neural systems, education and psychology, and has been supported by the EU H2020 MSCA-IF CARER-AID project (€183k, 703489) and the EPSRC project NUMBERS (£101k, EP/P030033/1). The work influenced the definition of the research priorities for the EU H2020 MSCA-ITN PERSEO project (2021-24, €4.0m, 955778), which is coordinated by the PRISCA Lab, University of Naples, and involves Sheffield Hallam as beneficiary. Also, within the SITRG, **Davies** has been exploring behavioural learning in cognitive neuromorphic robots. His work in [10.1109/tnnls.2018.2816518](#) is the key output of an EPSRC £1.2m project BABEL (EP/J004561/1) and presents the world-first attempt to use the SpiNNaker neuromorphic system to control the iCub humanoid robot, solving the real-world task of object-specific attention. **Alboul** has been combining virtual reality, robots and social networks to create novel immersive experiences in Cultural Heritage. Her work in [10.3390/su12020645](#) resulted in an invitation onto the Advisory Board of the CybSpeed project (EU MSCA-RISE-2017 -21).

The **Geometric Modelling and Pattern Recognition Group (GMPR)**, led by **Rodrigues**, explores novel image processing and data compression methods and AI-based pattern recognition, which has been awarded patents deriving from International Patent Application PCT/GB2016/050512, leading to internal innovation funding of £150K to commercially exploit the technologies. **Shenfield** specialises in AI-based pattern recognition methods, applying them to fault-finding in industrial processes. His work in [10.3390/s20185112](#) was a result of his role in the £544k BBSRC-funded “Next generation rice milling” project (BB/S020993/1, submitted under PI in UoA12), where a novel method was proposed for detecting maintenance issues using vibration data. This approach is now being used for condition monitoring of rice mill grinding plates. **Pranggono’s** area of research as part of the group is pattern recognition techniques for security and network applications [10.1109/TPWRD.2014.2300099](#).

The **Games Software Development Research Group (GSDRG)**, led by **Habgood**, has been exploring the possibilities afforded by Virtual Reality in serious games, including novel VR locomotion techniques to reduce side effects of VR use ([10.1109/VR.2018.8446130](#)), and creating a new type of narrative-driven, immersive experience for exploring Cultural Heritage sites, as the co-ordinating partner of the €1m EU H2020 REVEAL project (732599).

The **Medical Diagnostics Research Group (MDRG)**, led by **Saatchi**, has been investigating the effectiveness of applying AI to high-resolution thermal imaging in evaluating respiratory rate, vertebral fractures and juvenile idiopathic arthritis: [10.1159/000490546](#) and [10.1007/s11517-018-1806-3](#). The work, supported by MRC funding (£39k, SCH2397), in collaboration with Sheffield Children's Hospital and Sheffield University, developed a non-contact method of monitoring respiratory air flow and respiration rate. **Faust** and **Enamamu** specialise in the automated detection of atrial fibrillation and heart rate variability, using nonlinear methods, long short-term memory networks and wavelet transforms. Funded by Grow-MedTech with a proof of market grant, the findings of the paper [10.1016/j.cmpb.2019.04.018](#) led to a successful application for a Grow-MedTech proof of feasibility grant (£20k).

The **Networks Research Group (NRG)** is led by **Marchang** who is interested in protecting interconnected devices and network systems from cyber-threats, through innovative security and privacy solutions. The team, including **Otebelaku**, **Wang** and **Zargari**, explore the challenges of overcoming the limited power, bandwidth and connectivity of ad-hoc and sensor networks. **Wang** specialises in applying fuzzy neural networks to large scale computations, e.g. [10.1007/s11633-018-1120-4](#), in collaboration with the University of Huddersfield.

Additional areas of research across applied computing are supported directly through the Department and CRC, e.g.: **Dearden’s** work investigating sustainable and ethical ICT development for rural economies in third world countries (which underpins ICS3); **Ajao’s** work on how to harness social media for the dissemination of public health messages and novel methods of detecting miss-information in social media; **Bazli’s** research investigating how bio-molecular information can be used for data encryption; **Da Costa’s** use of evolutionary algorithms for letter identification in tremulous medieval handwriting; **Da Silva’s** application of novel self-adaptive role-based access controls to improve the security of business processes; **Ho’s** interest in the analysis of timed automata and in proving solutions to the problems of cyclic routing of Unmanned Aerial Vehicles; and **Samreen’s** work on the use of transferable knowledge for low-cost decision making in cloud environments, supported by an Amazon Web Services research grant.

Impact

The impact strategy of the Unit is consistent with the wider university's Transforming Lives strategy, committing us to making positive contributions to the cultural, economic, social and health challenges facing society. The annual round of individual research plans is used to identify activities and projects that are specifically targeted at promoting impact from research, and which receive QR funding support. Over the period, **Andrews**, **Polovina**, **Roast**, **Dearden**, **Rodrigues**, **Habgood** and **Saatchi** were supported in this way.

Through targeted support, and the oversight of **Roast** as the KT Champion, staff in the Unit have proactively engaged in institutional innovation and knowledge exchange activities, funded through ERDF awards and HEIF investment. This includes the Innovation Futures 2 scheme and the Sheffield Innovation Programme (1 and 2), through which Unit staff have undertaken innovation projects with 47 regional SMEs.

This has underpinned further developments and partnerships, leading to the funding of five Knowledge Transfer Projects (KTPs) during the period (Guildhawk, Infraglo, Bloor & Co., Highlander IT, and Balmoral Tanks), with a total KTP award value of £851,552.

The emphasis on end-user engagement and collaboration in the Unit's approach to research has underpinned growth in the impact activity throughout the period, with major impact arising from our more established work on security and humanitarian issues (CENTRIC) and digital innovations for use in education and cultural heritage (**Habgood**). Impact is also arising from new data compression methods (**Rodrigues**), novel approaches to HCI for working with spreadsheets (**Roast**) and new methods for diagnosing medical conditions (osteogenesis imperfecta and idiopathic arthritis) in children (**Saatchi**).

Open Research

University provision for open access (OA) for outputs and research data are detailed in the Institutional Environment Statement; initiatives have led to good awareness of open research and a high level of staff engagement. Staff and students are introduced to the principles of open research, including the University's Research archive (SHURA) and Research Data Archive (SHURDA) as the principal means through which publications and data sets are stored and shared. In line with policy, doctoral theses are available electronically via SHURA and made available to the public under a Creative Commons licence (CC BY-NC-ND). The University supports gold OA automatically when required by funders. It also funds gold OA of other papers, assessed on the basis of research excellence, with priority also given to researchers returning from parental leave and ECRs as a "career kick-start". Staff are encouraged to share OA publications through ResearchGate, Academia.edu and other academic networking sites, as well as via our professional networks and social media.

Research Integrity

Research undertaken within the Unit is underpinned by a strong ethical framework and commitment to research integrity, underpinned by the University's commitment to the Concordat to Support Research Integrity, as set out in the Institutional Statement. Collegiality is the central pillar of these processes, with a peer review college providing a conduit for the ethical review of research proposals. This system not only allows reviews to take place, but also strengthens links between academics in terms of awareness and understanding of each other's research activities. The majority of staff in the Unit serve as ethics reviewers. University training is provided and new reviewers are supervised by more experienced staff.

Interdisciplinary Research

Research in computer science and informatics has grown from its origins as part of the interdisciplinary C3RI, which supported and developed the interfaces between computing, human interaction, art and design and communications research. These links, co-location, and the wider, external networks and collaborations continue through the new research institute environment at Sheffield Hallam, with computer science and informatics now established as a Unit. This has engendered an environment that provides a robust disciplinary and scholarly home, from which contributions and collaborations are built that drive borderless research through interdisciplinarity. Examples include work with social sciences and communications specialists across security and law enforcement processes, and research with clinicians and practitioners in health and wellbeing. Specific examples include:

(i) The *Conceptual Structures Research Group* - **Andrews, Polovina** and UoA34 researchers in CENTRIC engaged with international collaborators in major interdisciplinary projects on combatting organised crime (ePOOLICE) and safeguarding the public in crisis situations

(ATHENA). Working with practitioners, the CSRG used conceptual graphs and taxonomies to model organised crime and crisis situations, innovated in novel sentiment analysis and natural language processing technologies to identify relevant online information, and used formal concept analysis to cluster and analyse the information. The research involved multiple collaborations with project partners across industry, academia, law enforcement agencies and the United Nations Interregional Crime and Justice Research Institute. The interdisciplinary nature and collaboration of the research resulted in outputs that have had significant impact in combatting crime and safeguarding humanitarian personnel (as detailed in ICS1 and ICS2).

(ii) The *Smart Interactive Technologies Research Group* has been involved in major multidisciplinary research projects with their research investigating the learning of numbers in children with special educational needs and the acceptance of robots to assist learning. As part of the EU-H2020-MSCA-IF-CARER-AID project (703489), this involved collaboration with the Department of Electrical Engineering and Information Technologies and the Department of Physics at the University of Naples Federico II, and the Department of Psychology at the University of Campania.

(iii) The *Medical Diagnostics Research Group* conducted interdisciplinary research through **Saatchi** with Sheffield Children's NHS Foundation Trust, supported by the Medical Research Council, to develop a device for diagnosing breathing disorders. **Faust's** research into nonlinear methods to discriminate fractionated electrograms in paroxysmal atrial fibrillation has involved collaboration with clinical researchers and mathematicians at the National Heart Centre of Singapore; the Department of Medicine, Columbia University, New York; and the Faculty of Medicine, University of Malaya.

Future Research Strategy

The future strategic orientation of the Unit builds on its establishment and growth during the REF2021 period and will reflect a commitment to the wider University objectives, as outlined in the Institutional Environment Statement. The Unit strategy is designed to ensure a strong research and innovation culture that delivers excellent performance, sustainable growth of research income and investment in research with economic, social and cultural impact.

Fundamental to the ambitions of the Unit from 2021 onwards is the plan to create a *Computer Science and Informatics Research Centre (CSIRC)* as the university-wide home for Unit 11 research. The new centre will be aligned to I2RI, along with CENTRIC and engineering related research centres.

The primary objectives of the CSIRC strategy will be to:

A. Consolidate and expand research and innovation culture and capacity. Widening the inclusion of staff university-wide via the operation of the new centre, and through continued staff recruitment that has an emphasis on proven track record of research and funding.

B. Continue development of ECRs. The Departments linked to the Unit will continue to invest significantly in staff development and mentoring of new staff and ECRs. The Unit will participate in the planned I2RI ECR forum, which will have an annual funded mechanism and a new ECR-led online publishing strand. I2RI also plans to host the BAME ECR national conference with a computer science strand.

C. Develop research excellence across the discipline by maintaining the vitality of research groups through regular group meetings, and meetings between research group leaders and the Head of the CSIRC; engaging with the I2RI strategic plan to build critical mass in fewer areas of focus, with targeted funds to leverage industry and public involvement. As the Unit expands, a focus will thus be to bring the groups together under broader thematic areas, aligned to critical mass and areas of strength.

D. Promote financial sustainability by expanding the primary sources of income generation beyond the current mainstay areas. The Unit will participate in the plans of I2RI to develop a framework for large scale funding schemes and the CSIRC will support proposal development and mentoring for proposal writing.

E. Enrich student learning and maintain an exceptional experience for our doctoral students by feeding PhD research into UG and PG taught teaching and projects, growing the cohort of PGR students and studentships, and building a bigger pool of PhD supervisors by supporting - through mentoring - the development of new staff and ECRs as PhD supervisors.

F. Enhance the current emphasis on undertaking applied research with economic, social and cultural impact. The CSIRC will run a series of focus events designed to identify research with high impact potential. Support via QR and local funding will be targeted at supporting impact development activities in areas identified as having high potential.

G. Foster greater collaboration with external academic and KE partners, with a view to securing greater income levels and research impact, by engaging with existing and new KE funding opportunities, such as InnovateUK and SIP2. Creating a new role of KE Lead within the CSIRC, thus expanding the current Computing Department activities in the Unit.

H. Enhance interdisciplinary research links with internal partners (notably CENTRIC) while establishing greater collaboration with other university centres of excellence, such as the Materials Engineering Research Institute, the National Centre for Excellence in Food Engineering, and the Advanced Wellbeing Research Centre. Interdisciplinary research will be supported by engaging with a series of Interdisciplinary Challenge events planned by I2RI.

The research strategy of the Unit aims to achieve the following outcomes in the next five years (each aim references the relevant objectives, A-H, above):

- Increase in staff profile of the Unit by 40% (A, B, C, H).
- Increase in staff PhDs by 30% and increase in PhD completions by 50% (A, E).
- Increase in external funding by 60% (A, D, G, H).
- Maintain at least six vibrant and successful Research Groups within the Unit and further develop areas of excellence, e.g. AI & robotics (**Di Nuovo**) and pattern recognition (**Pranggono, Shenfield**), whilst fostering potential new areas with high potential, e.g. detecting miss-information and 'fake news' (**Ajao**), and cybersecurity and edge system protection (**Marchang, Otebelaku, Wang, Zargari**) (A, B, C).
- Develop at least six areas of high impact, e.g. data compression (**Rodrigues**), AI for medical diagnostics (**Saatchi**), EQUUS spreadsheet visualisation (**Roast**) (A, C, D, F, G, H).
- Increase interdisciplinary research activity, as evidenced by joint projects and co-authorships (E, H).

2. People

Staffing Strategy

Research capacity has been promoted through the increase of additional research time for staff in the Department of Computing during the period, along with the strategic recruitment of research-active staff. This strategy has resulted in the external recruitment of candidates into strategically identified research areas, such as **Marchang** for his work in ad-hoc and sensor networks, **Da Costa** for her work with evolutionary algorithms and **Ajao** for his work in analysis of information in social media. Recruitment is undertaken in accordance with the University policies for equality, diversity and inclusion, with all staff involved in the recruitment and selection process required to have undertaken training, including on equal opportunities legislation and gender and diversity.

Career Development and Early-Career Researchers (ECR)

Our strategy is to build an inclusive and collaborative research environment, providing the requisite support and structures for researchers who are at different stages of their careers, as defined in the University's Academic Careers Framework (ACF) and *Vitae* Researcher Development Framework. It has three central objectives:

- To support research active staff to grow in a manner that is demonstrable via indicators such as high-quality outputs, external research income, research impact and career progression.
- To support ECRs by fostering a culture of research excellence that values quality research with impact and provides researchers with the resources, training and mentorship needed to become independent researchers.
- To support staff who wish to re-engage with research or engage with research in addition to professional practice.

These objectives are aligned with wider University objectives for researcher development and underpinned by the [Concordat to Support the Development of Researchers](#).

New academics receive a research induction and are invited to discuss their research plans with the Department Research Lead. The University-wide Early-Career Researcher Network, launched in 2018, promotes mentoring, collaboration and offers training opportunities. These approaches help develop a critical mass of active ECRs in the Unit, promoting interdisciplinary collaboration at an early career stage, as evidenced by inclusion of six ECRs in our submission (**Ajao, Conti, Davies, Enamamu, Otebolaku and Wang**).

Unit researchers are signposted to research development activities offered by the Sheffield Hallam Researcher Development (SHaRD) programme and the Library Research Support Team. These programmes offer training on topics such as leadership and management skills, research intelligence, grant writing, getting published, open access, research integrity and ethics, commercialisation and Intellectual Property.

Careful mentoring and sensitivity to the career aspirations of the individuals concerned saw the progression of **Domdouzis**, previously a Research Assistant, into a Senior Lectureship; **Zargari** into a Senior Lectureship; and **Gibson**, formerly Research Assistant, to a Senior Lectureship in the Department of Computing, then to Senior Research Fellow and more recently to Principal Research Fellow in CENTRIC.

Growing research profiles and leadership at higher levels, stimulated by mentorship and investment by the Unit, have contributed to the promotions of **Andrews** to Professor of Conceptual Structures in Computer Science, **Di Nuovo** promoted to Reader and then to Professor of Machine Intelligence, **Saatchi** to Professor of Medical Engineering, **Habgood** to Reader in Games Software Development, and **Polovina** to Reader.

The awarding of Professorships at Sheffield Hallam is managed by a diverse professoriate and individual mentoring is provided to aspiring applicants. The professoriate panel encourages draft applications for individual face-to-face and written feedback. Female staff have automatic access to the Aurora scheme, administered by AdvanceHE, and the internal Aspire scheme, developed by the Women Professors' Group - with a view to redressing the gender imbalance in senior roles. These structures have been beneficial in the case of **Da Costa**, who was recruited on the strength of impressive research credentials from external institutions, was soon appointed to Postgraduate Research Tutor for Computing, and is now being supported towards progression to Associate Professorship.

Research Time Allocation

Since its formation in 2016, the Computing Research Committee has been responsible for reviewing research plans and agreeing research time allocations for Computing staff. The CRC recommends the allocation of research time in addition to standard time allocations from role allowances, funded projects, and the universal Research and Scholarly Activity (RSA) allocation.

The Committee convenes annually to review individual research and innovation plans and consider developmental needs. The CRC has driven the strategy of growth with the annual investment in research time for the Unit ensuring that research active staff have between 20% and 40+% time allocations to implement their research plans.

The University REF Code of Practice (from spring 2019) applied best practice from the CRC to identify staff with Significant Responsibility for Research (SRfR). Hence, the identification of SRfR is now an institution-wide process based on the allocation of research time against specific, agreed research objectives.

Research Students

Postgraduate Research students are an integral part of our research community and environment, and are supported through a coordinated programme of recruitment, training, supervision, progression and support. From 2017, Sheffield Hallam has achieved sector-leading student satisfaction scores in the national Postgraduate Research Experience Survey (PRES) for computing students. The PRES results include high scores for satisfaction with supervision, resources, research culture, understanding of progress and attainment, rights and responsibilities, and opportunities for professional development.

In 2019, **94% of students said that overall, they are satisfied with their experience on the programme, in comparison to a sector average of 81%**. This outcome reflects the Unit's strong commitment to enhancing student experience, and the excellence of the PGR environment.

Management, Recruitment and Progression

The PhD programme is coordinated by a Head of Research Degrees, who leads a team of three academic Postgraduate Research Tutors (PGRTs), working in partnership with professional services staff and the central Doctoral School. UoA11 has a dedicated PGRT (**Da Costa**). The University Research Degrees Committee has overall responsibility for establishing regulations, policies and procedures, and includes representation from each institute and PGR team. Research degree provision meets quality thresholds as stipulated by the QAA UK *Quality Code Advice and Guidance for Research Degrees* and UKRI.

Recruitment

Policies and protocols are in place to ensure that admissions decisions are fair, consistent and reliable. PGRTs have overall responsibility for ensuring that applicants are appropriately qualified and ready to commence study at level 8. A standard PhD interview is used that covers subject knowledge, previous research training, motivation for PhD, career plans and any potential barriers or challenges in starting and completing a research degree. Applicants are advised by a PGRT and a prospective supervisor about how to strengthen a research proposal, and unsuccessful applicants following interview always receive constructive feedback to support any subsequent applications.

Studentships

A Graduate Teaching Assistant (GTA) PhD Studentship scheme was launched in 2014 that places independent, highly motivated researchers into the heart of academic departments, bringing with them a fresh research-informed approach to LTA practice and a visible ECR presence. Since the launch of the scheme, eight *GTA studentships* have been awarded to PGRs in UoA11, with a further student awarded the prestigious *Vice Chancellor's Scholarship* for her project with **Rodriguez** and **Shenfield** on a Visual Early Warning System, in collaboration with North Middlesex University Hospital (MRC funded project).

Progression and Support

PhD registration is formally completed at the Application for Approval of Research Programme stage at 3 months (6 months PT). Academic progress is assessed at Application for Confirmation of PhD stage at 15 months (27 months PT), when candidates submit a 6000-word report outlining research aims, the context for the work, methodological framework, initial findings/conclusions and

potential contribution to knowledge in their field. Candidates also present and defend their emerging thesis at a Research Institute Symposium, before submission of their report.

Supervisors and students are required to record supervision discussions and targets as a basis for monitoring progress against the agreed work plan and to support timely completion. Records are collected and logged to provide assurance that regular supervision is occurring and so we can intervene to offer support where there are concerns. The Head of Research Degrees employs evidence-based approaches to define excellence in student and supervisor support and to lead change. A key aspect of this is conducting a robust annual review of research degrees activity and improvement action planning - deploying evidence from the University's Annual Feedback and Monitoring Survey, the PRES, Staff Student Committee minutes, and sector indicators of quality in doctoral provision. We ensure that the constituency of our PGR Staff/Student Committee is representative of the diverse range of students on the programme, including differences in modes of study, gender, ethnicity, disability and neurodiversity.

Completions over the Period

There were 40 completions over the period. Notable is an increase from eight completions in 2013/14, to 15 completions in 2018/19, another testament to the 'sea-change' in research strategy for the Unit over the period.

Research Training and Supervision

Sheffield Hallam uses the *Vitae* Researcher Development Framework Planner and PGRs receive guidance on how to use this for Personal Development Planning and to identify training needs. Generic training as indicated by the *Vitae* Researcher Development Framework is co-ordinated by the central Doctoral School, whilst discipline-specific training is co-ordinated by the local Institute PGR team.

Each student is allocated at least two supervisors, with a minimum of two completions amongst the supervisory team. Regulations set a recommended minimum frequency for supervision meetings at every three weeks (six-to-eight weeks for PT students). All supervisors are required to attend regular update sessions organised by the Institute team and central Doctoral School. Topics are selected in response to student feedback, changes in research degrees procedure and with reference to the UKCGE Recognised Supervisor scheme.

In terms of the scholarly environment, the PGR team devised an alternating annual themed conference format as part of an innovative and interdisciplinary approach to staging PGR/ECR conferences. Our 'METHOD' themed conference provides a platform for discussions that focus on research process, practice, decisions and ethical challenges (rather than results); and the 'IMPACT' conference explores questions of research contribution, application, audience, value and impact. These themes enable students from different disciplines to come together to discuss their work and develop research culture skills, including practical experience of what a conversation across disciplines is like. They also provide an opportunity to orient to wider debates in the HE-sector and to rehearse arguments that are central to a thesis defence.

Equality and Diversity

The Unit is committed to embedding a culture of equality, diversity and inclusion for all staff and students, in line with University policies and equality objectives, that enable all our colleagues to contribute effectively to our research environment. Our approach to promoting inclusivity and the development of all staff is evidenced by this submission of 26.6 FTE, of whom 20% are female and 41% are of BAME backgrounds.

Working toward increased female and BAME representation among our staff is part of our action plan. This includes measures to explicitly state in job advertisements that applicants from BAME backgrounds and other underrepresented groups are encouraged, HR screening of advertisements to ensure inclusive language, and encouraging staff to promote opportunities through social media to increase the diversity of applicants.

Flexibility in relation to hours and location of work is strongly supported. Home-based working has been encouraged and supported, where appropriate, and colleagues can access University laptops to facilitate remote working. Online meetings were common practice pre-pandemic and are now widespread. Events are timed to ensure that a wide range of colleagues, including fractional staff and those with caring responsibilities, can participate fully.

The institution is accredited by the Athena SWAN Charter and has a Bronze Award, recognising its commitment to advancing and promoting women's careers in science, technology, engineering, maths and medicine (STEMM). **Da Costa** was invited to deliver the 2020 Athena Swan Lecture discussing the gender gap in science and has been invited to take part in the University's Athena Swan Team, where she is guiding department level initiatives, as well as organising and writing the next University submission for the Athena SWAN awards.

The Unit supports staff and PGRs to participate in research and research communities via funding for conferences, training, project expenses, open access, indexing, journal editing and other research activities. These are equally available to all staff, including those on fractional contracts and PhD students, regardless of mode of study. We are sensitive and supportive when staff and student's circumstances change and have a structured approach to returning to research or study after absence. PhD students are able to take a Break in Study if they are unable to engage with their studies. Staff and students are invited to a return to work or study meeting, to ensure the necessary support is in place for a return to the research environment.

3. Income, infrastructure and facilities

Research Funding Strategy and Income

Following the implementation of the strategy to support and grow UoA11 research, income has risen from £1,072,000 in the first half of the assessment period to £2,030,000 in the second half of the period, with a total of £3,102,000 income over the period. There has been a total of 42 funded projects with 16 different PIs.

Funding Strategies (Including Pathway to Outputs and Impact)

The funding strategy has sought to deliver collaborative relationships with partners inside and outside of academia, generate high quality research outputs, and create pathways to the achievement of high-level impact. This has been achieved by a combination of: (i) seed funding of research projects leading to the generation of larger research grants, (ii) support to develop relationships with academic and non-academic partners, and (iii) investment of QR and other internal funding to support research time, and provide administrative and scholastic support and mentoring for research projects.

This overall approach has borne fruit as detailed below:

Research Funding

Habgood secured internal investment to develop his collaboration in serious games and education with the University of Nottingham, investigating the use of eye-tracking in attention training games (£22.5k). He was subsequently supported in work planned time and mentorship (by **Andrews**) to secure the EU H2020 REVEAL project (€1m, 732599), investigating the use of VR and novel locomotion techniques for immersive, interactive games for cultural heritage. Investment for **Rodrigues** and the *GMPPR Group* has resulted in several successful externally funded project proposals, including the Medical Research Council funded AFRICCA project (Automatic Face Recognition in Critical Care) (£56k). **Saatchi** and the *AI in Medical Diagnostics Group* have been supported through QR funding in the development of medical applications of AI and thermal imaging, generating external support through the Medical Research Council funded project Sleep Apnoea Diagnosis in Children (£48k) and the Research England funded project, FractureScreen: Bone Fracture Screening Tool Utilising Artificial Intelligence and Thermal Imaging (£19k).

Di Nuovo, who was appointed in 2015 under the new research-oriented recruitment strategy, was supported in forming *The Smart Interactive Technologies Research Group* and subsequently securing several prestigious grants, including: the EU funded project Controlled Autonomous Robot for Early Detection and Rehabilitation of Autism (CARER-AID) in 2016 (€183k, 703489); the EPSRC funded Intellectual Disability Number Understanding Modelling in Behavioural Embodied Robotic Systems project (NUMBERS) in 2017 (£101k, EP/P030033/1); and, most recently, the EU funded Personalized Robotics as Service Oriented Applications (PERSEO) project (€4.0m, 955778).

Dearden has secured five grants through this period for his research in ICTD. His work includes improving the livelihoods and conditions of craft producers and farmers in developing economies (e.g. the £24k AHRC funded project: Creating, Connecting and Sustaining Links with the Indonesian Craft Economy) and embedding user centred design methodology into the informatics design process (e.g. the £40k EMI User Centred Design project funded by the Sheffield Teaching Hospitals NHS Foundation Trust).

Roast, as the KE Lead for Computing, has had continued success throughout the period, co-ordinating the securing of 11 Innovate UK, industry and KTP projects with a total award value of £1.49M.

Organisational and Scholarly Infrastructure

Developed from the interdisciplinary origins in C3RI, UoA11 has a core role in the new Industry and Innovation Research Institute (I2RI), which facilitates enhanced disciplinary collaboration; support for horizon scanning, pump-priming, collaboration and developing funding; and has a focus on enhancing research quality through staff development and mentoring. The institute coordinates scholarly activities such that researchers have access to regular interdisciplinary events and dialogues, with panels which are inclusive of gender, race and research career stage. Unit focused scholarly activities include workshops and a computing research seminar series, offering talks from invited external speakers, UoA11 researchers and doctoral students.

Research activity within the Unit is supported by the University's Research and Innovation Services (RIS) via a hub and spoke model. The central team provides governance, policy, funding KE and commercialisation support - with a dedicated operations team within the I2RI including new investment posts (2020) to drive research income and operations (Institute Manager) and knowledge exchange and innovation (Innovation Manager). The University's Library integrates high quality academic information resources with excellent IT facilities, enabling staff and student access to a wide range of journals and other scholarly materials.

Supporting Funding Applications

All external funding bids go through a rigorous preparation and authorisation process, including a triage and feedback stage overseen by I2RI. Staff are supported by research group leads early in the conceptualisation and writing processes, and by the I2RI peer review college in later stages of proposal development. RIS support the submission and approvals process, including costings and compliance with funder rules. RIS has specialist advisors for EU and regulated funding, along with innovation funding advisors. Successful proposals are supported by the institute team through initial start-up and project monitoring meetings to establish administrative, financial, technical and management assistance, and ensure project leaders are supported with project delivery.

Research Facilities

Dedicated research facilities available to the Unit include specialist facilities and workspaces across the research groups. Two user laboratories are dedicated to the study of human interaction regarding different technologies, media and environments. These include professional motion-capture equipment, eye-tracking technology and data analysis tools. External collaborators (e.g. SAS and Sony) have provided additional infrastructure, including data mining tools and professional games development stations, as part of our strategic commitments to expanding the presence and scope of the Steel Minions Games Studio and CENTRIC.

The Steel Minions Games Studio is located within the Department of Computing and contains a full suite of commercial-level games development stations on PC, Sony PlayStation and Sony PlayStation VR platforms. Several games have been developed and published by the studio, which is staffed by both academics and students, and directed by **Habgood**.

CENTRIC's office space contains a secure research working area to facilitate the security sensitive research. The CENTRIC VR Lab is configured to support the development and testing of virtual reality and augmented reality experiences for research and training, while the CENTRIC Open Source Intelligence Hub (OSINT Hub) is a dedicated resource that provides a secure and safe environment to explore the potential of OSINT.

The GMPR Group has a dedicated mini supercomputer used for research on data compression-encryption and Artificial Intelligence deep learning, and a number of high-quality 3D and 2D imaging cameras and associated specialist software.

For AI in medical diagnostics research there is a close collaboration with Sheffield Children's Hospital, where **Saatchi** is a member of their Research Board. Facilities at the hospital have been used extensively, including a dual-energy X-ray absorptiometry machine (to measure bone density), an MRI scanner (for skeletal examination), a Computerised Tomography machine (also for skeletal examination), an ultrasound machine and an X-ray radiograph machine (for bone fracture examination). The team also have two highly accurate infrared thermal cameras, used for thermography and a portable ultrasound machine.

The Centre for Automation and Robotics Research (CARR), where *The Smart Interactive Technologies Research Group* is situated, has a wide range of state-of-the-art robotics equipment including the Care-o-bot 4 (£190k), the Fetch Mobile Manipulator (£110k), various humanoid robots (Softbank Pepper, several NAOs), and indoor and outdoor mobile robotic platforms (Pioneer). The centre also manages a suite of advanced high-performance workstations for accelerated artificial intelligence computation, also including donations (value £16k) from semiconductor corporations like NVIDIA. Via the Sheffield Robotics collaboration, CARR also has access to extensive robotics facilities at Sheffield University.

4. Collaboration and contribution to the research base, economy and society

Collaborations, Networks and Partnerships

Robotics research at the University is part of the EPSRC-funded UK Robotics and Autonomous Systems (UK-RAS) Network, and the University is a founding partner of Sheffield Robotics, a collaboration between the University of Sheffield and Sheffield Hallam to share each other's facilities and equipment, as well as run joint research projects. In addition, **Di Nuovo** has been appointed as Digital Technology Theme Lead for the new Advanced Wellbeing Research Centre (AWRC), which was launched at Sheffield Hallam in 2019, supported by £14m funding from the Department of Health and Social Care and European Regional Development Fund. The AWRC focuses on interdisciplinary research linked to physical activity to improve health outcomes for long term conditions.

The Games Software Development Group, led by **Habgood**, have collaborated in interdisciplinary research with education researchers and schools in their work in serious games. The group has worked with the Department of Education investigating the role of visual programming tools in the development of young children's computational thinking, and with researchers in education at the University of Utrecht and the Sheffield UTC Academy Trust in investigating the educational effectiveness of immersive, narrative-driven VR games.

The Medical Diagnostics Research Group is partnered with Sheffield Children's Hospital (where **Saatchi** is a member of their Research Board). The team is now one of the leaders internationally in developing infrared imaging for paediatric healthcare.

In 2016 and 2017 **Rodrigues** was awarded two Research Mobility Grants (£28k) by The Royal Society, Royal Academy of Engineering and The UK Academy of Medical Sciences, in collaboration with the Brazilian National Council for State Research, to allow technology transfer of the high-performance computing of the GMPR Group's compression-encryption algorithms.

Contributions to the Economy and Society

The contribution to the economy and society is exemplified by our three impact case studies, summarised below:

ICS1 Building Technical Capability and Capacity in Law Enforcement Agencies for Combatting Crime and Terrorism: CENTRIC's open-source intelligence hub has improved access to digital intelligence for police forces across the UK, leading to successful outcomes for a number of law enforcement operations in counterterrorism, serious crime and child sexual exploitation. The cryptocurrency-based training, developed jointly by Europol and CENTRIC, was made available by Europol to law enforcement investigators across the world.

ICS2 Protecting Citizens in Crisis Situations and Safeguarding Humanitarian Personnel in High-Risk Environments: Research from CENTRIC in the application of formal concept analysis, data visualisation and user centred co-design has led to the development of the Security Communications and Analysis Network (SCAAN), launched in June 2017 by the United Nations International Organization for Migration (UN-IOM). SCAAN provides a security lifeline for frontline United Nations staff at risk of kidnapping, violence, bombing and natural disasters. It has been deployed by five UN agencies for its staff around the globe, in countries including Nigeria, Colombia, Greece, Turkey and South Sudan. SCAAN has enabled UN-IOM to rapidly communicate with and respond to staff in danger, increase security awareness within its personnel, and monitor their staff in real-time across the globe. Over 13,000 IOM staff are using SCAAN, operating in 158 different countries.

ICS3 People at the Heart of ICT for Socio-Economic Development: Research by **Dearden** has generated new software engineering methods and approaches in ICT for Development (ICTD) and ethical standards for research in ICTD. Collaborating with SAP, **Dearden's** research has informed the software engineering methodology, DRAMATICS. This methodology has been used to develop SAP's Rural Sourcing product, which has reached 500,000 small scale farmers across Africa, increasing incomes and improving sustainability, and led to the adoption of new ICT practices by an NGO working with marginal farmers in West Bengal.

Habgood's REVEAL project has led to two VR games being published on the Sony PlayStation Store, with profits going to the consortium partners. In particular, Dr Jenner's House, Museum and Garden (the location of the first game) was able to benefit, with the income playing an important part in keeping the museum viable. The income is also assisting the National Research Council of Italy to fund archaeology at the Imperial Forum of Augusta (the location of the second game).

Roast's EQUUS visualisation tool is licenced to VeryViz Ltd. for commercialisation. The company has made a core version of the tool (EQUUS V) available for user trialling and has a functionality richer version (EQUUS X) for professional use. Commercialisation plans are directed at the education and training sectors.

The Geometric Modelling and Pattern Recognition Research Group under **Rodrigues** has patented its data compression methods and the software is currently undergoing final trials before being commercially published.

Engaging Research Users, Diverse Communities and Publics

Di Nuovo and **Conti** have engaged a variety of audiences with their robotics research with talks as part of the British Computer Society lecture series, at an NVIDIA GPU Technology Conference, an IBM Watson Partner Day and a HealthXL Global Gathering. At the national government level, **Andrews** was invited to brief the UK Government on security innovations arising from the work of CENTRIC, and **Marchang** was asked to inform the Indian Government about applications of

Blockchain technology. In the media, notable examples of public engagement include **Di Nuovo's** article for BSA Today's Healthcare & Lifestyle Magazine, exploring the possibilities afforded by robots in social care, an interview on "Robots for Old People" for the BBC World Service, and a piece on robot carers for the Independent Newspaper. The Unit has also been active in promoting equality and diversity in its discipline, with **Da Costa** highlighting the gender gap and providing inspiration for girls and women via a number of outlets, including a Tech Week Keynote, an appearance on the Brazilian *Philosophy Coffee* TV show, an interview on the Brazilian Talk Show of COSERN, and an interview for the Brazilian *Our Science* show; while **Conti** gave an invited talk on autism at the Italian *Computer Science Without Borders Festival*.

Indicators of Wider Influence, Contributions to and Recognition by the Research Base

A. Journal Editorship

Di Nuovo: Associate Editor: 2019-current, Applied Sciences (MDPI); 2018-current, Robotics (MDPI); 2017-2020, Cognitive System Research (Elsevier). Guest Editor: 2017 IEEE Transactions on Cognitive and Developmental Systems, Special Issue on "Cognitive Agents and Robots for Human-Centred Systems" (IEEE); 2016 International Journal of Social Robotics, Special Issue on "New Frontiers of Assistive Robotics for Elderly" (Springer). **Andrews** and **Polovina** were Editors-in-Chief of the International Journal of Smart Applications and Conceptual Structures. **Da Costa** is Associate Editor of IET Biometrics. **Marchang** was guest editor for a special issue of the International Journal of Environmental Research and Public Health on the topic "Secure IoT Adoption and Its Challenges in Health and Wellbeing Applications". **Faust** is on the Editorial Board of MDPI Signals, MDPI IJERPH and the CTACT Journal on Communication Technology; and was a special issue guest editor for Pattern Recognition Letters: Smart Pattern Recognition for Medical Informatics, 2018, and Artificial Intelligence in Medicine: Deep Learning for Medical Applications, 2019. **Shenfield** was guest editor for a Sustainability special issue on "Green ICT, Artificial Intelligence and Smart Cities". **Conti** is Topic Co-Editor for Frontiers in Psychology on "The impact of COVID-19 pandemic on school, university, and education: Psychological experiences, interventions, prevention, and future perspectives". **Saatchi** is a Topic Editor for Healthcare, MPDI, and was a guest editor for The Mediterranean Journal of Computers and Networks special issue on 'Wireless Networks'.

B. Participation on Grants Committees

Dearden was a UKRI panel member for GCRF proposals in 2018. He also reviewed grant proposals for the Velux Foundation (Netherlands) in 2017, reviewed grant proposals and promotion applications for the South African National Research Foundation, 2014-2020, and reviewed a fellowship proposal for the Rockefeller Foundation in 2016. **Di Nuovo** is an evaluator for seven funding bodies: the European Commission H2020 - FET/MSCA programmes, the National Council of Science and Technology of Chile, the Flanders Research Foundation, the Czech Science Foundation, EPSRC (UK) and EU Public End-User Driven Technological Innovation, ECHORD++. **Rodrigues** was a grant reviewer in 2015 for The Leverhulme Trust. **Da Costa** is a Newton Fund reviewer. **Conti** was an evaluator for the European Commission for the Marie Skłodowska-Curie Individual Fellowships call 2020. **Da Silva** is a reviewer for the Brazilian Society for the Advancement of Science.

C. Prizes

Notable prizes awarded in the Unit include *Best Application Paper 2018* awarded to **Di Nuovo** by the International Federation for the Promotion of Mechanism and Machine Interaction, and the *Best Paper Award* won by **Di Nuovo** at SISTEMI INTELLIGENTI 2015. **Da Costa** was awarded the *Best Paper Prize* at the Computer Forensic Workshop at SBSEG, 2019. **Dearden** won the ACM Special Interest Group on Computer-Human Interaction: Social Impact Award in 2021 (see ICS3), and in 2019 **Shenfield** won the *ICT Express Best Paper Award*.

D. Membership of Research Council Committees/Evaluator

Dearden is a member of the EPSRC Peer Review College. **Wang** is a member of the British Machine Vision Association. **Rodrigues** is a member of the Bulgarian committee on "Creation and Development of Centres of Excellence". **Faust** is an Advisor to the Estonian Research Council. **Da Silva** is Member of the Technical Committee on Digital Identity Management of the Brazilian

National Research and Education Network. **Di Nuovo** is an evaluator for the European Commission, EPSRC (UK), the National Council of Science and Technology of Chile, the Czech Science Foundation, and the Kazakhstan National Centre of Science and Technology Evaluation.

E. Conference Chair Roles

Staff in the Unit have played significant roles in the academic discourse of the discipline over the period. Notable examples include **Da Costa** Chair of the 2018 Congress of the Brazilian Computer Society, **Di Nuovo** Chair of the 2019 IEEE RO-MAN BioRobotics Workshop and General Chair of the 2016 International Workshop on Hybrid Metaheuristics, **Andrews** Chair of the 5th Conceptual Structures: Tools and Interoperability Workshop at ICCS 2016, and **Dearden** Co-Chair for AfriCHI 2016.

F. Visiting Positions, Invited Keynotes and Lectures

Staff in the Unit have been recognised for their research and expertise throughout the period and have been invited by more than 50 institutions, organisations and conferences to give keynotes and lectures. Notable examples include **Dearden** in 2015 as Visiting Professor for the University of Cape Town and for the International Institute for Information Technology, Bangalore. **Conti** is Visiting Professor at the University of Catania, Italy. In 2015, **Andrews** was invited speaker on the use of social media in crisis management at the European Commission Research Executive Agency and has given invited talks at the National Research University, Moscow and at Sheffield University. **Di Nuovo** has given 12 keynotes and eight invited lectures, including talks for the Alan Turing Institute Workshop on Robotics and AI for Health and Social Care, the International Psychogeriatric Association: Robots and Technology Symposium, and the British Computer Society Lecture series. **Rodrigues** gave keynotes at the 2016 Kelaniya International Conference on Advances in Computing and Technology and at the 2016 Brazilian Symposium on Information Systems. **Da Costa** gave an invited lecture at Trinity College Dublin in 2018, and **Faust** gave a keynote in 2019 at the University of South Florida Colleges of Business and Medicine. **Shenfield** gave an invited lecture at De Montfort University, and **Ho** gave an invited talk at the Research Institute of the Free State of Bavaria. **Alboul** was an invited plenary speaker at the 2018 International Conference on Robotics & Mechatronics and Social Implementations, and **Conti** gave an invited talk at the 2018 Conference on Technologies for Learning and Communication in Autism.

G. Journal Reviewing

Staff in the Unit are reviewers for over 80 international journals and conferences, including: Information Sciences, IEEE Transactions on Vehicular Technology, IEEE Transactions on Cybernetics, IEEE Transactions on Fuzzy Systems, ACM Computing Surveys, IEEE Robotics and Automation Letters, Engineering Applications of Artificial Intelligence, Pattern Recognition Letters, and Sensors (MDPI).