Unit-level environment template (REF5b)

Institution: The University of Brighton

Unit of assessment: B11 – Computer Science and Informatics

1. Unit context and structure, research and impact strategy

1.1. Context and structure

Computer science researchers at the University of Brighton (UoB) have led a submission to the RAE/REF since 1992. This REF2021 submission builds on our expertise in diagrammatic reasoning and natural language generation with strategic expansion into software security and privacy. We have significantly advanced our mission to lead high-quality research with global partners (47% of outputs are co-authored with international collaborators, vs 34% in REF2014), whilst delivering impact to national and international business and NGOs. Since REF2014 the UoA has more than doubled research income, joined three Doctoral Training Programmes, and almost quadrupled PGR conferrals.

Our expertise (15 FTE staff, 30 PGRs) is focussed on three research themes:
- ***Visual Computing (VC):*** diagrammatic reasoning, visual languages, and computer graphics with cultural heritage applications (primary interest for 7 FTE, including Reader **Fish**, ECR **Baimagambetov**; and 9 PGRs)
- ***Language and Data Processing (LDP):*** natural language generation and mathematical/statistical methods for data analysis (5 FTE, including Professor **Belz**, Reader **Harris**; 10 PGRs)
- ***Secure Systems Engineering (SSE):*** software systems security and privacy (3 FTE, including Professor **Mouratidis**, ECR **Polatidis**; 11 PGRs).

The UoA is based within the School of Computing, Engineering and Mathematics. The Centre for Secure, Intelligent and Usable Systems (CSIUS) was founded in 2017 (approved as a Centre of Research and Enterprise Excellence (CORE) – see REF5a), providing a hub for UoA B11 researchers (12 staff, 16 PGRs, directed by **Mouratidis**) and acting as a vehicle for interdisciplinary links with health, humanities, media and education (section 4). CSIUS encompasses the SSE and VC themes and some of LDP; it is a European leader in SSE, evidenced by the award of EU projects (with total budget of over €20m; see section 3), and official recognition from the EU as a Cybersecurity Competence Centre.

1.2. Research and impact strategy

1.2.1. Achievement of strategic aims for research and impact since 2014

Our strategic aims, revised from those set out in REF2014, and evidence of their achievement are outlined below:

Aim 1: Grow talent and develop future research leaders. As a result of our cultural heritage expertise, we lead UoB's contribution to the EPSRC Science and Engineering in Arts, Heritage, and Archaeology CDT (SEAHA), which together with ESRC-South Coast DTP membership and the EPSRC DTP formula allocation, provided 8 studentships. This, alongside strategic UoB investment of 21 studentships, enriched our PGR environment, and PGR conferrals increased by 278% (39.7 vs 10.5 in REF2014). As a result of our strategic focus on supporting ECRs applying for EPSRC First Grants/New Investigator Awards (Section 2.16), we were successful with 4 applications including 3 that were led by staff first entered as ECRs in REF2014. Ongoing developmental support has enabled 4 staff who were ECRs in 2014 (**Burton, Fish, Kapetanakis, Rodriguez**) to secure £1.12m from EPSRC and industry.

Aim 2: Invest in existing and emerging areas, extending our international influence.
Adjusting to a changing research landscape, we identified SSE as a strategic focus and invested in its growth. We recruited a professorial lead (**Mouratidis**), who led on a targeted recruitment strategy as part of succession planning. Establishment of the SSE area has resulted in securing 6 EU Horizon 2020 grants with 15+ international partners. Internal initiatives (eg Sabbaticals; see

2.14), have led to international discipline hopping in VC (**Burton**, EPSRC, EP/R043949/1) and EU COST action (**Belz**, IC1307) leadership involving 28 countries in LDP (see 4.1).

Aim 3: Enhance impact capacity through partnership. We established over 40 non-HEI collaborative partners (including Yahoo, Nokia, Fujitsu, The Pensions Regulator and GSK), and our income includes over 75% with industrial collaborators, charities or policy makers. Internal initiatives (Innovation funding; see 2.14), networking events, and our international outlook stimulated partnership growth, whilst strategic investment (£479k) in laboratories, equipment (see 3.2), and CSIUS, provided essential infrastructure for collaborative impact-generating activity.

Aim 4: Grow a balanced and diverse funding portfolio. By leveraging our national and international networks, and non-HEI partnerships, our research income has grown by 153% with £1.18m from the EU, whilst industrial engagement, aligned with impact generation strategies, led to an over 400% increase in income (to £1.64m) secured from industry and Innovate UK. Diversification strategies for interdisciplinary projects led to 2 new Leverhulme Trust projects to model cavities in the spinal column, and to guide the development of foundational approaches to reasoning.

1.2.2. Intellectual achievements

Our staff have built upon long-standing external collaborations, yielding intellectual achievements within the research themes (examples below), whilst developing new interdisciplinarity links and enabling impact.

Visual Computing create theory, algorithms and software for diagrammatic visualisations, used for scientific data presentation, and undertake fundamental evaluations of human perception and their ability to interpret and reason with diagrams (**Blake**) in our bespoke laboratories (see 3.1). Visual interfaces are designed and developed for personal resource management (**Fish**, with Di Chiara, Poste Italiane – Software Factory Napoli, Italy), and to enhance the automotive engineering data set exploration and analysis capabilities of industrial partners (**Fish**, with Gargiulo, Fiat Chrysler Automobiles, involving multiple site evaluations with industrial analysts). We achieved major advances in Shape Understanding in computer graphics via mesh saliency detection (Song), that are used as benchmarks in the field. Our creation of innovative methods and tools for the design, development, fabrication and evaluation of interpretative experiences of 3D artefacts in cultural heritage collections has driven change in the sector, being deployed by major heritage institutions across the UK, Europe and Brazil (**Rodriguez**, [ICS_Heritage]).

Language and Data Processing have produced new methods for 2D image descriptions capable for the first time of conveying 3D spatial relationships (**Belz**, with Malta University) as well as a framework for conceptualising, annotating and automatically extracting information about drug nonadherence from patient-generated text (**Belz,** with Brighton and Sussex Medical School and Sussex Partnership NHS Foundation Trust). A breakthrough achievement was the development of methods to estimate covariance matrices for big data applications (eg genomics, cancer research, signal processing, and financial mathematics) thereby reducing computational costs (**Touloumis**).

Secure Software Engineering has, for the very first time in academia and industry, integrated privacy into DevOps practises by developing processes and software tools that automate crucial privacy-related processes (**Mouratidis, Pavlidis**). PGR students, and international collaborations, were integral in the development of novel frameworks that introduce essential security and privacy requirements in Cloud Computing, Business Processes and the Internet of Things (IoT) domains (**Fish, Mouratidis**), realised with open-source tools (see 1.4). The creation of next generation software platforms to support GDPR compliance, supported by novel privacy-by-design conceptual languages, data mapping views, and data breach analysis and response techniques, generated international interest (eg Greek/Latvian/Thailand Data Protection Authorities, Information Commissioner's Office) and acclaim, with the work being awarded EU cyberwatching Project of the Month for May 2019 (**Mouratidis, Pavlidis**).

1.2.3. Enabling interdisciplinary research and impact

Underpinning our research and impact success is an ethos of interdisciplinary working. Supported by UoB's strategic investment of Quality-Related research funding (QR), CSIUS has used £107k to develop interdisciplinary research agendas and collaborations by promoting multi-disciplinary membership (eg with Health Sciences), 'application-led' seminars, and start-up interdisciplinary projects (eg leading to securing H2020 AI4HealthSec 883273 - see 3.1). CSIUS activities have led to research outputs (eg new methods for the management of security-incidents in Healthcare Critical Information Infrastructure Environments) and projects at disciplinary interfaces (eg at Health and Security/Privacy). Moreover, interactions with other UoB Centres and Schools have enabled interdisciplinary advances (eg **Harris**, with Phillips from the School of Pharmacy and Biomolecular Sciences, created a new poroelastic model of the spinal cord and utilised video experiments to develop new cell migration models). The joint Brighton and Sussex Medical School (BSMS) enables collaborative interdisciplinary research, including through PGR co-operation (eg 3D visualisation technologies for medical training, supervised by **Rodriguez** and Smith, returned in UoA A3). Our income diversification strategy of targeting funders specifically supportive of interdisciplinarity led to our 2 Leverhulme Trust projects (one in collaboration with University of Cambridge).

Our philosophy of engaging non-HEI partners fully within the research lifecycle ensures outcome relevance and increases impact potential. We have supported staff to initiate and sustain partner engagement through a £479k strategic investment in laboratories and equipment (eg 3D scanners, HPCs required for cultural heritage and data processing applications; see 3.2), together with innovation funding (eg to build demonstrable privacy software; see 2.14). VC have leveraged longstanding partnerships to develop digital applications for cultural heritage that enabled practitioners and institutions to transform the way young people, visually impaired, online and visitor audiences experience and value cultural heritage collections (**Rodriguez**, [ICS_Heritage]). In SSE, via EU projects (see 3.1) and new consortia, we have empowered public and private sector organisations across Europe (eg PDMFC, a leading Portuguese company in ICT and Information Security) to adopt a privacy-by-design approach across software services to ensure compliance with privacy laws and regulations (**Mouratidis**, [ICS_PrivacySoftware]).

To increase translation of our ideas into industry, we encourage staff to engage in knowledge exchange programmes through tailored sessions at development days delivered by our knowledge exchange managers; all our staff attended at least one such session. In this census period, we increased the number of Knowledge Transfer Partnerships (KTPs) from 3 in REF2014 to 10 (£1.17m). This engagement ranked us 2nd in the UK for KTP income in the Information & Comms sector (for data released up to 2018). We widen awareness of our research and impact achievements by co-authoring with our non-HEI partners (21% of submitted outputs), together with dissemination via social media outlets and a quarterly business newsletter that reaches over 450 SMEs.

1.3. Research and impact strategy to 2026

Our ambition is to yield academic, economic and societal gains through close connection with partner needs. Over the next five years we will:

Aim 1: Advance the Artificial Intelligence agenda, exploiting synergies between themes.
Focussing our specialised expertise in an AI context, we will support adoption in key areas such as health (eg linking with security and privacy via the AI4HealthSec project; see 3.1), whilst contributing to advancing the national agendas in accountability, ethics and transparency (eg via AI-explanations, visual interfaces for user-centred data analytics). Success measures will include securing funding from UKRI and Horizon Europe, and development of an AI Impact Case Study for the next REF.

Aim 2: Grow and strengthen research partnerships and collaborations. Strategic investment in existing and emerging areas, together with Centre activities (eg interdisciplinary start-up projects, industrial knowledge exchange events), will facilitate an increase in numbers of

collaborative partnerships. Together with income diversification strategies (eg to MRC), and staff time for grant writing (internal funding, sabbaticals)*, **we will double the number of external grant applications and income generated on collaborative projects**.

Aim 3: Extend the reach, significance and accessibility of our research. By leveraging established networks and partnerships*, we will **enhance our international reach and facilitate further impact generation** (measured by numbers of collaborative international and industrial outputs, and industrial or societal effects). We will **double the number of KTPs,** with staff benefitting from an expanded UoB KTP professional support base. The generation of interdisciplinary projects across themes will enable exploitation of new routes to impact (eg data processing within humanities, ArtsDRIVA; see 4.3). We will **increase the volume of openly available research-related artefacts**, aiming to make all non-confidential research software, data and models freely accessible (eg via GitHub).

Aim 4: Enlarge our UoA research base and develop new research and enterprise leaders. Leveraging collaborative project growth, we will increase post-doctoral researcher numbers. By supporting research independence and recruiting active researchers in response to natural staff turnover, we will increase the diversity and quality of our research expertise. We will support our Readers to share leadership roles and will **increase the number of staff with UKCGE-recognised research supervisor awards to capitalise on our PGR growth in the international student market.**

1.4. Open research and research integrity

We follow the Research Integrity and Ethics policies and procedures set at University level, and training provided through the UoB Researcher Development Programme. A three-tier ethics review system operates for all research projects, overseen by a University-level policy committee, ensuring data protection in all our research. We contribute to the development of international standards relating to GDPR (eg **Mouratidis** via membership of the BSI IOT/001 Privacy-by-Design standards committee).

We share research findings and data in line with UoB policies and guidance (REF5a). UoA Open Access compliance is 95% for the 105 journal articles or conference proceedings with ISSN produced since 2018, and we make research-related artefacts freely available, instilling in PGR students an open research culture. For example, **Kapetanakis,** with Jorro-Aragoneses (Complutense University of Madrid), contributed to the creation of the open-source COLIBRI recommender system (over 36k downloads); the R package ShrinkCovMat (**Touloumis**), realising new covariance matrix methods, is freely available for reuse and has been downloaded more than 26k times; and tools including those to support security analysis in IoT systems developed by PGR Mavropoulos (supervised by **Fish, Mouratidis**) are publicly available on GitHub. **Belz** organises international shared task competitions under the GenChal umbrella, including the Surface Realisation shared tasks (2018-2020), and the ReproGen shared task which aims to establish how reproducible past evaluations have been and how to design and report human evaluations to increase reproducibility.

2. <u>People</u>

2.1. Staffing strategy and staff development

2.1.1. Staff Profile

Our 15 FTE Category A staff comprises 13% Professors, 33% Readers/Principal Lecturers, 53% Senior Lecturers, with 13% being ECRs, and 20% female; the median age range is 41-50, 7% are reported as black, Asian, and minority ethnic (BAME), and 100% are on permanent contracts, work full-time and have no declared disabilities. This profile aligns with the Advance HE sector average for median age range (41-50) and gender balance (23% female), but includes a higher proportion of full-time staff (sector: 68%), and a lower proportion with disabilities (sector: 5%) and reported as BAME (sector: 27%). During the census period 47% of Category A staff were recruited, and 60% were promoted at least once.

2.1.2. Staffing strategy

Our ambition is to provide an inspiring and inclusive environment for staff, students and visitors. Strategic goals for our staff are to: recruit outstanding researchers with potential to become future leaders, whilst expanding our collaborative networks; refocus expertise, adjusting to a changing research landscape, into areas of strategic growth that utilise close non-HEI partnerships to address essential societal and industrial needs. Appointed in 2014 to a new strategic professorial post, **Mouratidis** established our presence in Secure Software Engineering. We rejuvenated our staff base, accounting for staff turnover, shifting some visual computing expertise to support growth of SSE and data processing, with: **Pavlidis**, ECR **Polatidis** directly supporting SSE; **Fallahkhair**, ECR **Baimagambetov** bringing Human Computer Interaction in cultural heritage expertise and industrial Software Engineering experience; **Chernov** from Bedfordshire and **Touloumis** from Cambridge, recruited into his first lecturing post, bringing expertise in complex data processing methods and algorithms.

2.1.3. Support mechanisms for staff development

Annual Staff Development Reviews (SDRs) reflect on staff development, research achievements, and future goals. The Research Mentoring Framework, introduced in 2016, and School Mentoring Lead (**Winter**) encourage mentors and mentees to discuss and plan career development and progress. All new staff and ECRs are allocated a research mentor and senior staff participate in 360-degree feedback. Mid-Career Researchers (MCRs) and senior staff are supported by university-level leadership programmes (eg **Belz, Fish, Rodriguez** participated in a research leadership scheme in 2014 and have subsequently held international leadership roles (eg steering committee membership for IEEE Symposium on Visual Languages & Human-Centric Computing; see 4.4)). We implement devolved leadership to develop future leaders, including **Rodriguez** as the CSIUS Associate Director for Research Strategy, and **Touloumis** for Researcher Development.

2.1.4. Internal research and enterprise funding for staff development

We support all staff, via mentoring, in applying for competitive University research funding schemes (REF5a), enabling the development of research leaders, collaboration, publication and grant applications. Rising Stars awards, which provide a first experience of leading a project, enabled grant submissions (Savostyanov's EPSRC New Investigator grant), international collaboration and publication (**Touloumis,** with Cambridge and Columbia Universities). Innovation Funding (**Mouratidis**, £20k) to develop industrially focussed grant applications, returned £120k (Innovate UK) and led to a Privacy toolkit, presented to potential investors during the final round of the CyberASUP programme. We benefited from 2 semester-long sabbaticals delivering international collaboration and grant applications (eg **Burton** organised the Indian Winter School on Diagrams, in Kolkata, extending collaborations with semioticians and philosophers, leading to his EPSRC Discipline-hopping grant on the Applied Semiotics of Visual Modelling).

We invest QR funds, allocated via Schools, for staff development. Three staff benefitted from time releases of up to 0.2 FTE for 1-2 years enabling publication and grant application development (eg **Winter**'s Royal Society Newton Mobility grant application to support collaborative research and development of long-term links with Universidade Federal Pelotas, Brazil). In addition to conference support funds, seedcorn funding further enabled international network development (**Fish,** ECR **Polatidis** with the University of Salerno, Italy), industrial collaboration investigating the use of machine learning for enriching visual collections with metadata (**Rodriguez**), building an IoT blockchain testbed (ECR **Polatidis**) and funding a series of task-oriented empirical studies (**Blake**).

2.1.5. External developmental activities and leadership recognition

We have placed a strategic focus on supporting staff exchanges and secondments, developing new expertise and partnerships. For example, **Burton** spent 9 months working alongside experts

in semiotics at the University of Bologna (via EP/R043949/1), leading to international collaborative workshop organisation (Philosophy of Notation, Bologna, ~30 participants from Europe, Japan and USA). **Kapetanakis** was seconded for 1 year to a London start-up (Gluru Ltd) to lead their research and development teams in natural language processing using deep neural networks. Two outputs from **Kapetanakis** helped drive inward-investment and the company subsequently doubled in size.

We encourage staff engagement with international event leadership roles with our staff undertaking 12 international workshops as Chairs (for conferences, see 4.4). External activities, internal schemes and mentoring help staff develop research leadership skills that are then rewarded through the promotion framework: 60% of staff have been promoted at least once (67% of females, 58% of males), with staff obtaining permanent contracts following PGR (ECR **Baimagambetov**) and postdoctoral Research Fellow (PDRF) positions (ECR **Polatidis**); **Baimagambetov, Chernov, Polatidis, Pavlidis** have been promoted from Lecturer to Senior Lecturer; at Mid-Career Researcher (MCR) and senior staff level, **Kapetanakis, Rodriguez, Touloumis** have been promoted to Principal Lecturer (PL), **Fish** from Principal Research Fellow (PRF) to Reader, and **Belz** from Reader to Professor.

2.1.6. Targeted support for ECRs

All new staff are given workload relief to establish their research (0.1 FTE for 2 years). PDRFs are offered teaching opportunities to expand their professional portfolio, and gain experience via interaction with project partners, improving career prospects. Out of 10 EU-funded (Horizon 2020) fixed-term PDRFs supported in SSE: 6 have taken up lectureships in the UK (Brighton, Robert Gordon, York) and internationally (Jordan, Greece, Nigeria); 1 secured a position as a Software Engineer in a recognised industry leader for Metadata Management Solutions (Collibra, Belgium), 1 works for the European Union Agency for Network and Information Security (ENISA); and 2 are active PDRFs (50% female) on current H2020 CyberSANE (833683) and AI4HealthSec projects. We employ a policy of co-supervision for PGR students, pairing ECRs with established supervisors to provide mentored supervisory experience (eg ECR **Polatidis** co-supervises 2 PGRs alongside **Kapetanakis** and **Pavlidis**). Coaching ECRs in developing applications for EPSRC New Investigator grants led to 4 new awards in the census period. Our approach in developing ECRs into research leaders has led to 13 out of 15 Category A staff originally being hired as ECRs at UoB. Other ECRs are prepared for subsequent successful academic or industrial careers, eg Ali (Senior Lecturer, Brunel), Zhou (Senior Lecturer, Loughborough), Delaney (Bloomberg LP, a global leader in business and financial data) and Nicholson (a solution architect at Hastings Direct, a digitally focused general insurance provider).

2.2. Postgraduate Research students

Development of the next generation of researchers is central to our approach, with expansion of our PGR base being central to this. We have 30 active PGRs and have achieved a 278% increase in PGR conferrals (to 39.7, with headcount 45). Growth is underpinned by diversifying funding sources, including staff fee waivers (**Blake, Winter**), industry and self-funded students (14 conferrals) and international government studentships (14 conferrals from Middle East countries). Our success via the EPSRC DTP-algorithm, ESRC South Coast DTP, and EPSRC CDT SEAHA in collaboration with Oxford University and University College London (7 active out of 8 awarded), was augmented by UoB-funded investment via competitive studentships (8 active out of 21). UoB's engagement in SEAHA (£4.7m, 2014-2022) is led by us through our expertise in cultural heritage (linked to Visual Computing). The programme has funded 4 of our PGRs, supported by 8 external industrial and heritage partners (eg Smithsonian Museum Conservation Institute, Victoria and Albert Museums) and world leading research groups (eg Fraunhofer IGD) under the CDT's tri-partite (academic, industrial, heritage) supervision model.

2.2.1. PGR recruitment and progression

The Brighton Doctoral College (BDC) oversees PGR student recruitment and monitors all EDI-related aspects of selection. In 2019, intervention by the University's BAME Student Ambassador

led to a change in recruitment practices to ensure equity and inclusion (REF5a). Our PGRs are 33% female, 20% have declared disability, and 23% reported as BAME. Enhanced visibility via online information about PhD research programmes, supervisors and research specialisms has improved PGR recruitment. We actively support applications from international PGR candidates from disadvantaged countries: of 21 UoB studentships received by us, 5 arose from competitive international scholarships (4 conferrals, 1 active) for PGRs from countries including Nigeria, Pakistan and Sudan. All PGR students have 2+ supervisors and a thesis panel to monitor progress, complemented by annual reviews to ensure progress. Since REF2014, 2 PGR Coordinators have been appointed by the School (**Fallahkhair, Harris**), coordinating the recruitment of PGR students with the BDC, and subsequently acting as first point of contact for PGRs and academics, aiming to enhance the PGR experience.

2.2.2. PGR training and support

New students receive a training-needs analysis, mapped against the Vitae Researcher Development Framework. Methods and impact training are provided by the BDC Postgraduate Researcher Development Programme. PGRs are encouraged to contribute to, and are supported to attend, at least 2 conferences during their studies including at least one overseas, and we use QR funds to supplement UoB's Conference Support fund. This enables our PGRs to develop their skills and networks, and has led to best paper awards (eg by PGR Samaroudi, with **Rodriguez**, at the Immersive Learning Research Network Conference in London, and the Eurographics Workshop on Graphics and Cultural Heritage in Vienna in 2018).

Networking opportunities are provided by DTP cohort events, an annual UoB-wide Festival of Postgraduate Research, and a School-based annual PGR Research Conference. SEAHA students spend the first year of their doctoral programme at UCL undertaking a Master's degree, ensuring a common basis across the different institutions and facilitating PGR community development; SEAHA training events (4.4.1) also admit 2 of our PGRs, funded by other means, as SEAHA-aligned students. Training PGRs to become research leaders, we support leadership role engagement (eg the 3rd International Conference on Science and Engineering in Arts, Heritage, and Archaeology was chaired by our PGR Webb).

2.2.3. PGR supervision and destinations

We have experienced supervisors covering all themes (eg **Mouratidis** in SSE, **Fish** in VC, and **Harris** in LDP, all with 8+ completions), with **Fish** recently awarded UKCGE recognised research supervisor status, and external co-supervision further expands our supervisory capacity. Career destinations for our PGRs include lectureships and senior positions internationally (eg Abubakar, Rector at Katsina State Institute of Technology and Management, Nigeria), research posts and senior roles in the UK and international industrial sectors (eg Mavropoulos, Head of Engineering, CyberLens, Greece; Burlutskiy, AI Scientist, Early Oncology R&D, AstraZenica, Cambridge, UK).

2.3. Ensuring equality, diversity and inclusivity

We are a multinational community of staff, students and visitors from diverse backgrounds, and countries (eg Greece, Iran, Mexico, Nigeria, Russia and Turkey). At the heart of our commitment to an inclusive workplace is the wellbeing of our staff and PGRs, our culture expects issues to be discussed openly and staff undertake mandatory online training (EDI Essentials, Unconscious Bias, Interviewing & Recruitment, Managing Diversity, Dignity at Work). The University provides additional training (eg on LGBTQ, trans and disability awareness).

UoB is one of only 17 HEIs to hold a Bronze Race Equality Charter, is a Disability Confident Level 2 employer, holds Athena SWAN institutional Bronze, and is in the latest submission of the Stonewall Top 100. **Fallahkhair, Fish** and **Rodriguez** are on the School's Athena SWAN committee, contributing towards the School's bronze award in 2019. Our Athena SWAN action plan's progress is overseen by the School Equality & Diversity Committee, comprising academic, administrative and technical staff and PGRs. All decision-making committees at School and Unit level are representative in terms of seniority and gender, with membership scrutinised by the committees. Equality impacts are assessed for policy documents developed by these committees

and for all conference, training and research support allocations. Internal funding schemes are subject to an annual EIA (since 2017) that covers gender, disability and ethnicity.

Measures are in place at University, School and UoA level to promote inclusion and deliver the University EDI Strategic Plan and Race Equality Charter Action Plan. We have established BAME mentoring and allyship programmes, offer bespoke promotion workshops, and leadership and management development programmes for BAME staff. EDI aspects of appointments, including for internal research leadership roles (eg Centre Directors), are overseen by Human Resources. Women hold key School leadership roles, including the Associate Dean for Research and Enterprise, and the Computing Research Lead (**Belz**). Computing researchers were represented by 5 members in the University's Women of Impact celebration of International Women's Day 2018.

Researcher development activities run during core hours and rotate between days so that part-time staff and those with caring responsibilities are not disadvantaged. Schools offer a Returning to Research Fund to support staff returning from an extended period of parental leave or ill health. We strive to minimise the use of fixed-term contracts to provide stability for career development: 97.4% eligible staff and 100% of those with a significant responsibility for research are on permanent contracts, as are all lecturing staff appointed since 2014.

Our REF Leadership Team comprised 6 staff with 33% female, and 50% of our Impact Case Studies were led by women. Output selection and attribution of outputs were agreed by the Leadership Team at a selection meeting, with the primary inclusion criteria being pre-agreed quality judgements following internal reviews. An equality impact assessment on selection and attribution of outputs demonstrated proportionality for mid-career stage researchers (53% outputs selected vs 52% staff) with slight variations for gender (14% outputs vs 20% female staff), early career stage (5% ECR vs 10% staff) and within the professoriate (16% vs 10% staff).

3. Income, infrastructure and facilities

3.1. Research funding, strategies and awards

Our strategy for generating research income, to ensure sustainability and facilitate growth, is to provide financial and mentoring support for all new researchers so that they can obtain external grants, whilst encouraging staff to diversify income sources. Since 2014, we targeted (i) EU funding, extending our international influence; (ii) Innovate UK/industry funding, increasing alignment of research and impact activities; (iii) EPSRC, developing new researchers into future leaders; (iv) UK charities for diversification. We have used expertise in the CSIUS to support a widening of our base of funders (to include EU, EPSRC, Leverhulme Trust, and Innovate UK) and external research funding has increased by 153% since REF2014.

Our EU income has grown (£1.18m vs £439k in 2014), with 7 projects, primarily aligned with the Digital Security and the Information and Communication Technologies topics of Horizon 2020. This stems from our income strategy of targeting these funding streams and developing large networks across academia, industry and public administration. By utilising our expertise and positioning, we address challenges from multiple perspectives. H2020 projects VisiOn (653642, £292k, 12 partners, overall budget €3.16m)/MITIGATE (653212, £255k, 12 partners overall budget €3.55m)/DEFeND (787068, £311k, 10 partners, overall budget €3.33m), adopt citizens/industrial/software engineering perspectives, creating novel privacy-by-design methodologies that have financial, business and societal impact on organisations across the world [ICS_PrivacySoftware]. We develop state-of-the-art methods and techniques to deal with cybersecurity challenges in specific sectors including telecommunications (H2020 SESAME 671596, £234k, 19 partners, overall budget €8.27m), critical infrastructures (ongoing H2020 CyberSANE, 15 partners, overall budget €6.15m) and health care (ongoing H2020 AI4HealthSec, 13 partners, overall budget €5m). These projects have enhanced our international reputation and influence through collaboration with 28 industrial partners (eg Atos, a global leader in digital transformation, and a European leader in Cybersecurity, Cloud and Supercomputing) in 13

countries (eg Portugal, Spain, Austria, Italy, UK), 5 national research centres (Greece, Italy, Slovenia, France, Germany), 6 universities (in Belgium, Greece, Germany, Italy, UK), 15 end users including hospitals (eg Klinikum, one of the largest municipal hospitals in Europe), ports (eg Piraeus Port Authority in Athens), public authorities and critical infrastrucutures (in Spain, Germany, Greece, Bulgaria, France, Italy). Building on our earlier EPSRC Network on Vision & Language (EP/H018557/1, 250+ members), **Belz** led an international team of researchers from Greece, Ireland, Belgium, Spain and Italy in applying for a European COST Action (acceptance rate < 5%) for a European Network on Integrating Language & Vision (£520k overall budget); Action networking was reported to EU as underpinning 35 successful scientific missions, initiating new research collaborations and 7 new projects (including 3 H2020 projects).

Our industrial-facing funding has grown (£1.64m vs £328k in REF2014), and we have broadened the number of Innovate UK grant holders (8 vs 3). This stems from our industry engagement strategy, utilising extensive networking (eg at Strata Data) and leveraging existing partnerships to enable co-application for Innovate UK grants. For example, a successful pilot project with Network Rail and South-eastern on Visual Data Mining on Big Data (2014-15, £99k) led to **Kapetanakis'** project for South-eastern, Govia, on Big Data Analytics on sub-threshold delays using fuzzy and probabilistic reasoning (2015-17, budget of £2.1m, with £378k to UoB), developing accurate models to reduce train delays and thereby reduce fines imposed. Impact generated from Innovate UK's KTPs has included job creation (2 engineers) at BCMY (Knowledge management development for Enterprise Systems, £175k). Software developed for Graduate Recruitment Bureau's tool (Autonomous user profile identification for social engines, £137k) contributed to the opening of a London site with a dedicated team (Expert Hire, 6 recruiters). Another Innovate UK project (**Mouratidis**, £120k) focused on the commercialisation of privacy engineering research and the development of a tool to support DevOps to incorporate privacy analysis and compliance. Data analysis from the ongoing Innovate UK project with Parafix Ltd (**Belz**, £72k, with UoB budget £243k) to automate planning and scheduling processes using artificial intelligence has uncovered insights about cutting tool pressure changes, leading to efficiency gains for the company.

Training and investment in future leaders have grown our income generation capacity, with 6 staff (all ECRs in 2014) attracting funding (£1.35m) during the census period, accounting for 36% of our total. Our income diversification strategy yielded a new source of funding from UK charities (Leverhulme Trust, £295k) for interdisciplinary projects: A Mathematical Model of the Formation and Growth of Cavities in the Spinal Cord (**Harris**), where the results of biological experiments provided the model's numerical values of parameters (eg density, Young's modulus) of the tissues in the cord; and Accessible Reasoning with Diagrams (Stapleton), which used empirical studies to guide the development of foundational approaches to reasoning, building upon one of our four EPSRC new investigator projects (total £374k) on readability of proofs in diagrammatic logics (**Burton,** EP/M011763/1).

3.2. Infrastructure supporting research and impact

UoB Research Services play a pivotal role in assisting our staff to secure funding by providing support for bid-writing, identifying commercial opportunities, sourcing industry and community partners, administering projects, and facilitating training workshops. Research management is supported by the School's Research & Enterprise Committee, which administer QR funds and manage research integrity, researcher development and local delivery of the Research Concordat Implementation Plan; membership is inclusive in terms of gender and career stage, and include research theme leads, Centre Directors, ECR, PDRF and PGR representatives. **Mouratidis** directs CSIUS, supported by Associate Directors **Rodriguez** for Research Strategy, **Touloumis** for Researcher Development, and Fotis (from UoA A3) for Outreach.

The offices used by our staff and PGRs in the Cockcroft building, together with laboratories, were renovated through a £26m refurbishment in 2015, which won an *Architects' Journal* Retrofit Award, providing a modern academic and learning environment.

![REF2021]

Visual Computing Facilities. The Digitisation Lab, led by **Rodriguez**, is used to underpin research for applications within industry, the creative sectors and cultural heritage institutions. It contains specialist processing equipment (£51k), fixed and hand-held 3D scanners (£73k), a Reflectance Transformation Imaging (RTI) acquisition dome, VR equipment, and a stereolithography 3D printer. The laboratory and equipment are essential for the digitisation of artefacts and environments, and the production of accurate digital images and 3D models. This supported 7 PGR projects, research training for postgraduates and heritage professionals on digitisation, facilitated research proposal development in collaboration with other institutions [ICS_Heritage]. The User Centred Design Laboratory, led by **Fallahkhair**, contains eye-tracking and EEG technologies to acquire perceptual, cognitive and behavioural knowledge of participants, with wide screen HD monitors to display visual stimuli, together with a noise-free, constant-temperature controlled room. It has been essential for conducting empirical experiments, deepening understanding of the efficacy of diagrams (**Blake, Touloumis**) and informing the design of smart environments for cultural heritage (**Fallahkhair**).

Language and Data Processing Facilities. Investment in a dedicated high-performance computer cluster (£70k), hosted by our School, together with 0.4FTE technical support (supported by QR funds) for development and maintenance, enables fast parallel computations for uninterrupted in-house simulations. This complements our existing collections of high memory machines and servers. Together, these have been essential in applying deep learning techniques and visual computing capabilities, underpinning 5 PGR projects. Additionally, we use the Data Laboratory, which provides offices and computers for up to 20 businesses as well as meeting and event space, and computational facilities (service owner **Belz**) funded by a Local Growth Fund grant and linked to the £1.1m EDRF-funded Digital Research Innovation Value Accelerator project (DRIVA, returned in UoA34; see 4.3)**.**

Secure Systems Engineering Facilities. The Security & Privacy Laboratories, created in 2014, led by **Mouratidis,** contain high performance computers to support the design and analysis of security and privacy requirements, and network isolation capabilities for penetration testing and malware detection (isolated from the University network). Our research results (methodologies, tools) are installed in the labs, providing specialised capabilities for use in contract research and research projects. Internet of Things equipment support the development of innovative testbeds, enabling security and privacy experiments (eg a testbed was used to establish guidelines for potential attacks in IoT devices in the project SESAME).

We share resources across HEIs in collaborative research for essential computations utilising in-house and external (eg Savastayanov, a Balena High Performance Computing Service at the University of Bath) machines. Close interactions with industry have led to Nvidia Inc contributing hardware, software and instructor time in delivering tutorials for a Summer School on Integrating Vision and Language with Deep Learning, which in 2016 trained approximately 100 EU students, academics and industry representatives (**Belz**). Google contribute 1 month of staff time and support including access to their internal evaluation services every year for the annual Multilingual Surface Realisation Shared Task (**Belz**), enabling benchmark development for evaluation. Gluru Ltd. provide access to several Terabytes of their datasets for Natural Language Processing research and access to their hardware, used in the creation of semi-automatic business knowledge acquisition mechanisms and domain feature decoding (**Kapetanakis** with Amin, German Research Center for Artificial Intelligence).

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

4.1. Arrangements to support collaboration with academic colleagues at other HEIs

Our researchers have collaborated with 55+ research institutes, drawn from 16 countries, including 17 UK institutes (eg Cambridge, Liverpool, Oxford), and 38+ international (eg Sapienza, Stanford). Collaboration with academic partners is facilitated by: financial support, mentoring and annual SDRs, where staff are encouraged to develop their academic profile through research networks

and consortia; solidifying partnerships and enlarging the reach of our networks via events and projects; and promoting PGR supervisory teams to include external members.

Financial support (see 2.14) facilitates collaboration with existing networks (eg **Touloumis'** Rising Stars award enabled collaboration with CRUK Cambridge Institute and EMBL-European Bioinformatics Institute on statistical analysis of multi-tissue gene expression data). Our participation in discipline-specific workshops, events and conferences, external HEI visits (eg **Fish**, ECR **Polatidis** to the University of Salerno), and invitations of national experts to deliver seminars are supported using QR funds. We also apply for external funding for international visitors (eg Royal Academy of Engineering funding for Prof. Mylopoulos with University of Toronto, Canada, which included workshop organisation, with attendance from 8 Universities); international research scholars and fellows (eg from Malta, China, France, Japan, and Brazil) visit for periods of up to several months.

Collaborations with the University of Sussex have been enabled via a Brighton-Sussex Collaborative Research Fund (eg £10k to **Rodriguez** for community technologies). The joint Brighton and Sussex Medical School facilitates collaborative interdisciplinary research between Universities, benefitting us via: collaboration in knowledge extraction from patient-generated texts (**Belz**); co-supervision of PGR students (**Rodriguez**); diffusion tensor brain image method development identifying Multiple Sclerosis (**Fish,** with PGR Elsheikh, Zhou (Loughborough) and Cercignani (Sussex)).

National and European funding has enabled joint research projects and collaborations with academic colleagues in other institutions. Notable examples of success include:
- 6 EU-funded projects with **Mouratidis** in Secure Software Engineering (with total value of over €20m) have grown our collaborative networks with 15 HEIs worldwide.
- Leadership of international networks (chaired by **Belz**) integrating language and vision, supported by an EU COST action, with 28 countries represented on the management board. The COST action led to the organisation of 7 workshops (co-located with leading conferences in various fields), 3 summer schools, 23 publications, around 30 datasets for multi-lingual annotations for existing datasets, 7 funded collaborative projects, and 170 new researchers introduced to the field through training schools, involving leading researchers from industry and academia.

The successful outcome of these arrangements is evidenced by: 93% Category A staff have co-published with researchers from other HEIs; 74% of the outputs in this submission are co-authored with external academic partners, with 47% written with non-UK partners from 13 different countries; over 37% of our external research income has other HEI partners.

4.2. Relationships with research users and how these enrich the research environment

To develop interdisciplinary user-inspired research that contributes to addressing societal challenges we initiate and maintain long-term relationships with users and beneficiaries in areas such as Digital Health, Digital Humanities, Education and Critical Infrastructure. We engage stakeholders to elicit their requirements in practice, working with them throughout the research lifecycle to ensure relevance and increase societal impact potential. This has led to collaborations with over 40 different national and international companies, public sector organisations and charities, including Google, Nokia, The Pensions Regulator, as well as museums and heritage organisations (eg Royal Pavilion Museums); our submitted outputs include 21% with industrial co-authors, and external research income includes over 75% with industrial collaborators, charities or policy makers.

Initial engagement with users and beneficiaries is facilitated by UoB Research Services, through networking (eg at our Industrial Advisory board, with companies such as East Sussex County Council, American Express and Gatwick Airport) and via past (eg 3D-COFORM project, see [ICS_Heritage]) and present consortium projects (eg DRIVA, making Gatwick's data more accessible). Partnerships are developed and maintained via mechanisms such as: internal funding to pilot projects (eg **Rodriguez**'s Impact Award to co-develop research solutions that addressed

Brighton Museum and Art Gallery's needs for development of the new Archaeology Gallery); direct engagement with partners via KTP projects (eg Family Law Partners), knowledge exchange with stakeholders through visits, as well as collaborative arrangements for PGR training (eg SEAHA PGRs with both heritage and industrial partners supervising). Successful partnerships and events generate further contracts (eg with The Pensions Regulator, on data analytics and AI to support the Automatic Enrolment directorate, that led to workshops with The Pensions Regulator's security team). We also host visitors from commercial and third-sector organisations (eg BCMY Ltd, NHS trusts, Nokia) to facilitate opportunities for prolonged interactions, and staff take secondments in companies (eg **Kapetanakis** with Gluru Ltd).

International stakeholder interaction enhances the reach of our researchers' influence and impact. The European network on integrating vision and language (**Belz**) had over 400 members from 28 countries, supporting links with over 30 institutions and companies around the world (with co-applicants including Yahoo Inc.). **Rodriguez** hosted a collaborative workshop *Strategies for safeguarding and (re)building resilient cultural heritage* (funded by the Accelerator Scheme for International Networks and Impacts), with users and stakeholders from Brazil, Egypt and Mexico co-designing a research agenda.

4.3. Contributions to the sustainability of our disciplines and responsiveness to national and international priorities and initiatives

Our staff provide intellectual leadership to national and international committees of professional associations and research networks. For example, **Mouratidis**' participation in UK wide activities (eg Expert Fellow of the ESPRC NetworkPlus SPRITE+), membership of standards committees (eg BSI IOT/001 Privacy-by-Design, providing the UK contribution to the upcoming ISO 23485 standard and IST/015 Software and Systems Engineering), and leadership of international working Groups (eg elected Vice-Chair of the International Federation for Information Processing WG11.14 on Secure Engineering), enabled us to lead international strategy on Secure Engineering and international standards development on Privacy-by-Design. Standard evaluation methodology is essential in ensuring sustainability of a discipline; towards this goal, **Belz** has led an international effort in benchmarking and evaluation focused around Shared Task organisation since 2007 (recently on Surface Realisation and Reproducibility of Human Evaluations in Natural Language Generation).

Our research exploring user engagement and experience of ubiquitous computing technologies in heritage settings (**Winter**) has increased awareness, shared best-practice guidelines, and improved learning in the heritage sector by disseminating findings through trade shows, events and professional publications that have reached over 20,000 online, and over 8,000 in print. **Kapetanakis**' proposal to the Rail Safety and Standards Board for changing the performance monitoring standards by National Train Operator Companies was accepted as a deliverable (considered to be a standard by 2025).

We provide essential support for industry-facing data-processing needs, facilitating interdisciplinary research and increasing regional competitiveness. For example, the *Digital Research & Innovation Value Accelerator* (DRIVA) project (returned in UoA34) is a collaboration with Gatwick Airport Ltd, making their flight and commercial data accessible to SMEs to create new products and services for the open market. **Belz, Touloumis**, Song (with Sinah from Brighton Business School) co-developed AI/data solutions with SMEs, creating software to access live Gatwick Airport flight and commercial data; we provided data sets and training to over 100 SMEs via the Data Driven UXD programme that included Vodafone, IBM, Tesco and Booking.com. The linked *ArtsDRIVA* project introduced 13 artists to emerging technologies (immersive, interactive, 5G and quantum computing) to utilise in their practices.

4.4. Wider influence, contributions to and recognition by our disciplines

We advise nationally and internationally, with **Rodriguez** being a member of the Executive Board of the Eurographics Association, and **Winter** advising the Management Board of QueenSpark Books on digital strategy. **Belz** chaired the Management Board for the European COST Action on

Integrating Vision and Language (IC1307, 2014-2018), was a member of EPSRC Network RefNet (EP/J019615/1, 2012-2016), and served as lead reviewer for 4 European Commission reviews of FP7 and H2020 projects. **Mouratidis** has been chair/member of international funding body panels (eg EU, Norway, Belgium, and Australia), and served on advisory boards (eg EU-funded projects SHIELD/GUARD, the US Department of Energy), and a working group from the European CyberSecurity Agency tasked to define and propose a skills-and-competences framework for cybersecurity). Within the UK's remit, **Belz, Fish, Mouratidis**, and **Rodriguez** are EPSRC Peer Review College members, and **Belz** regularly serves on EPSRC funding prioritisation panels.

Fish, Mouratidis, Rodriguez have been members of 10 editorial boards (eg **Mouratidis** for the *Requirements Engineering Journal*; **Rodriguez** for the ACM *Journal of Computing and Cultural Heritage*) and 5 staff (**Belz, Burton, Fish, Mouratidis, Pavlidis**) have guest-edited 6 special issues (eg **Belz** for the *Journal of Natural Language Engineering*, **Burton** for the *Journal of Logic, Language and Information*, and **Fish** as managing guest editor for the *Journal of Visual Languages and Computing*).

We have held leadership roles in major conferences and symposia, for example: Steering Committee membership (eg IEEE Symposium on Visual Languages & Human-Centric Computing (**Fish**), IEEE International Conference on Research Challenges in Information Science (**Mouratidis**), and Eurographics Working group of Computer Graphics and Cultural Heritage (**Rodriguez**)), and 11 general/program chair roles by 4 staff (**Belz, Fish, Harris, Mouratidis**) with **Harris, Mouratidis** organising international conferences in Brighton. We provide academic leadership via keynotes at International Conferences (eg on Natural Language Generation (**Belz**) and the Next Generation Enterprise Modelling in the Age of Internet of Things (**Mouratidis**)). Researchers have received recognition: best paper awards (eg Digital Heritage (**Rodriguez**), Diagrams (**Burton**)), and nomination (**Belz**) for the NAACL Test of Time Award 2018, which recognizes two papers each year for their lasting impact on the Computational Linguistics field.

4.4.1. Cooperation and collaborative arrangements for PGR training

Whilst participating in collaborative and interdisciplinary DTP/CDTs, we supported all 57 SEAHA PGRs across UoB, UCL and Oxford, through digital training on the SEAHA MRes, bespoke international training in collaboration with colleagues at CNR-ISTI (Pisa) and follow-up training on Heritage Enterprise and Digital Methods. The 3rd International Conference on Science and Engineering in Arts, Heritage, and Archaeology was held at the University of Brighton, 2017, run by SEAHA PGRs, and chaired by our PGR Webb, with around 140 participants and presenters from UK, Poland, Germany and Belgium. In 2018, we organised the largest of the annual SEAHA residential training events, at which 44 PGR students from Brighton/UCL/Oxford engaged in two days of PhD and career development events and student-led planning and support activities. Additionally, staff provide PGR training internationally (eg in 2017, **Fish** delivered an advanced interdisciplinary course at the European Summer School in Logic, Language and Information, which attracts around 400 participants every year).

4.5. Engagement with diverse communities and publics through research

We engage industry, public authorities and beneficiaries by organising seminars and knowledge exchange events (eg on Privacy and GDPR, attended by local companies and public authorities such as NHS and the Brighton and Hove City Council) and exhibitions (eg at the Museum and Heritage show). We raise awareness of our research and impact via engagement with wider public-facing events including school/college and public talks national and regional science/STEM fairs and festivals (eg Brighton Digital Festival, Universities Week, and the SEAHA Mobile Heritage Lab at British Science Festival). We target events at communities across age ranges (eg CoderDojo Brighton, a free coding club for young people encouraging creativity; Codefest (ECR **Baimagambetov**), a monthly term-time event with software engineering problem-solving activities, with mentors from local companies such as Brandwatch; presentations to Lewes University of the 3rd age (**Pavlidis**, cyber security research to around 50 members), and organise events with community stakeholders (eg **Belz**, international AI research competitions with Google). **Rodriguez**

undertook collaborative research with community partners and the University of Sussex to investigate technologies that connect communities to their urban landscape, leading to a best paper award at the Eurographics Workshop on Graphics and Cultural Heritage. PGRs and staff in the STEM ambassadors programme engage in community activities, complementing active research engagement, such as enabling school children, disadvantaged young people and visually-impaired audiences to interact with history and arts in more inclusive and engaging ways (**Rodriguez**) – eg via 3D-printed replicas that help (partially) blind audiences to experience works of art normally exhibited in glass cabinets, and creative ways to interact with local histories to support wellbeing and a sense of identity within members of the community (see [ICS_Heritage]).