

Institution: Birkbeck, University of London
Unit of Assessment: 11 – Computer Science and Informatics
<p>1. Unit context and structure, research and impact strategy</p> <p>1.1 Unit context and structure</p> <p>Founded in 1957, the Department of Computer Science and Information Systems is one of the oldest computing departments world-wide and one of four departments in the School of Business, Economics and Informatics (BEI). Historically a small department (18.8 FTE returned to REF2014), we have grown by 30% since REF2014. Having a long-established reputation in data management and computational intelligence, we have evolved into a world-leading centre in Algorithms, Data Science, Knowledge Representation, and Verification, as evidenced by (i) our Q1 position for research outputs in REF2014; (ii) subsequent 70% growth in the number of publications, in such highly prestigious venues as JACM, AIJ, JAIR, JMLR, IEEE TKDE, IEEE TSE, TPAMI, FOCS, PODS, LICS, IJCAI; (iii) 50% growth in research grant awards; (iv) rapidly expanding network of international, interdisciplinary, industrial and public-sector collaborators.</p> <p>Our REF2014 results highlighted our strengths in algorithms and theory, leading to an ambitious development programme which expanded and refocused our research into three Groups: <i>Knowledge Representation & Data Management</i>, <i>Experimental Data Science</i> and <i>Algorithms, Verification & Software</i>; and two research Centres: <i>Birkbeck Institute for Data Analytics (BIDA)</i> and <i>Birkbeck Knowledge Lab (BKL)</i>. The Groups focus on specific areas of computer science, with fluid boundaries facilitating inter-group collaborations and departmental cohesion. The Centres are interdisciplinary, spearheading new collaborations within and beyond the College.</p> <p>BIDA was established in 2015 to focus the development of college-wide research in data science, combining our expertise with domain-specific knowledge from all disciplinary areas at Birkbeck: Sciences, Social Sciences, Law, Arts & Humanities.</p> <p>BKL was launched in 2016, extending the legacy of the London Knowledge Lab (2001–2015), a joint initiative with the UCL Institute of Education. BKL's research draws upon multi- and interdisciplinary perspectives to investigate how digital technologies are transforming our learning, working and cultural lives.</p> <p>The Department's research capacity is further enhanced through participation in the Institute of Coding (IoC), a national OfS initiative to address the UK's digital skills gap, with 60+ universities and industry partners. The IoC synergistically supports our research and impact strategies through academic staff posts and targeted programme development (for example, through a collaborative PGCert with the British Library and National Archives).</p> <p>1.2 Research strategy</p> <p>We develop our research and impact strategies in the context of two overarching aims:</p> <ul style="list-style-type: none"> - to be a world-leading research centre with complementary expertise in both theoretical and applied computer science; - driven by Birkbeck's mission, to develop flexible opportunities in cutting-edge computer science for a diverse range of students, particularly working Londoners. <p>The latter provides unique opportunities to engage, through students bringing real-world problems driven by their work environment, with a range of IT companies and other</p>

organisations.

Review of REF2014 research strategy. As stated in our REF2014 environment narrative, we have “investigated fundamental research problems whose solution advances knowledge in the discipline, and undertaken collaborative research with partners from other disciplines that exploits and enhances our expertise” and have achieved significant advances in all the focus areas identified therein (see below).

Post-REF2014 strategy. Our research strategy over the census period, and continuing into the next five years, is based on seven key principles:

- (R1) Recruit internationally excellent staff whose research enhances our strategic directions (detailed below).
- (R2) Foster an environment of inclusivity and equality, where all researchers can thrive and fulfil their potential.
- (R3) Promote research leadership, enabling collaboration and support within and across the research groups, including support for research career development.
- (R4) Maintain research excellence and innovation in core computer science, investigating fundamental problems in both theory and practice, spearheading the development of new technologies.
- (R5) Carry out world-leading interdisciplinary research, recognising that computer science is pervasive in all areas of society.
- (R6) Amplify the impact of our research through collaboration with organisations across the public, private and third sectors—nationally, internationally and across disciplines.
- (R7) Provide all researchers with the environment they need to pursue research in their chosen fields, including purpose-built labs, specialist hardware and software, and financial and technical support.

Our research and impact strategies are articulated and regularly reviewed by the department’s Research Committee, which horizon scans to identify strategically significant emerging areas of research that dovetail with our existing profile. Its Chair is a member of the School Research Committee, which develops and shares best practice across BEI, monitors research student recruitment and progression, and works to enhance BEI’s research environment. The School Research Committee articulates with the College’s Research Committee and Research Strategy Group through its Chair, BEI’s Assistant Dean for Research (this was Poulouvassilis till summer 2015 when she was appointed Deputy Dean for Research Enhancement, continuing as a BEI member of the College Research Committee).

Strategic areas of research. Driven by principles (R1)-(R7), we made significant changes to our staffing and organisation of research since REF2014, reflecting our vision for this census period and beyond:

First, we refocused the Computational Intelligence group into *Experimental Data Science* (EDS) and enhanced it with three new appointments, researching data-driven methods for cloud computing, bioinformatics and IoT security.

In recognition of our emerging strength in *Algorithms, Verification & Software* (AVS), we created a new group in this area and further strengthened it by appointing two experts in automated program analysis/verification and algorithmic graph theory.

The Information Management & Web Technologies group was refocused to *Knowledge Representation & Data Management* (KRDM) accompanied by three appointments: in database theory, constraint satisfaction and logic; in temporal representation and reasoning; and in graph data management.

Finally, we launched BIDA and recruited its director, who also strengthens EDS research in experimental algorithmics and data analytics.

KRDM strategy. KRDM addresses challenges arising from managing, accessing and exploiting heterogeneous high-volume data, with particular focus on logic-based approaches, database theory and related computational complexity problems, and graph data management. Since REF2014 we have published 70+ journal and 170+ conference papers, including in highly prestigious venues such as JACM (2 papers), AIJ(5), TOCL(4), LMCS(2), JAIR(2), PODS(5), ICDT(3), IJCAI(7), LICS(6).

Ground-breaking advances have been made in first-order model checking in the context of database theory, logic and complexity (H.Chen); complexity and succinctness theory for ontology-based data access (OBDA); foundations of temporal OBDA; and game-theoretic characterisations of query inseparability and of the Horn fragments of description and first-order guarded logics (Kontchakov, Ryzhikov, Zakharyashev). Fundamental advances have been made in flexible processing of graph queries (Cali, Poullovassilis, Wood); quality-driven data integration (Martin, Poullovassilis); designing the first logic-based language for JSON transformation and querying (Hidders); and axiomatising and classifying algebras of functions with composition and (anti)domain/range – an emergent tool in program verification (Mikulas).

Over the next five years KRDM will focus on:

- fundamental problems in computer science logic, including database theory, constraint satisfaction, complexity of ontology-mediated query answering;
- developing techniques for intelligent data access, integration and management, in collaboration with partners in industry;
- contributing to new industry standards in graph data management.

AVS strategy. AVS addresses the efficiency of computation, including theory, design and implementation, with several foci: foundations of algorithms and computational complexity, algorithm design, and analysis and verification of systems and software. Since REF2014, we have published 65+ journal and 85+ conference papers, including in ACM TAGL (1 paper), JCSS(4), IEEE TSE(2), ACM TOCT(3), FOCS(3), SODA(1), STACS(2), ICALP(4), POPL(2), ICSE(2), LICS(2), IJCAR(3), TACAS(3), CONCUR(3).

We do not shy away from notorious open problems, such as reconstructing graph properties from subsets of vertex-deleted subgraphs (Fenner); inference of worst-case runtime complexity bounds and size bounds for programs on integers; satisfiability for separation logic with inductive definitions (Fuhs); the Matroid variation of the famous Secretary Problem; and lower bounds for relaxed locally decodable codes (Lachish). Other ground-breaking advances have been made in propositional knowledge representation and order theory (Razgon); and algorithmic techniques for sparse graph classes (Reidl). Fundamental advances have been made in automated termination analysis of higher-order programs (Fuhs); theory and verification algorithms for fuzzy systems (Han); automated approaches to improve the quality of API documentation (T.Chen); and algorithmic approaches to learning neural architecture hyperparameters and ensembles (Magoulas).

Over the next five years AVS will focus on:

- computational complexity; randomised algorithms and their applications; theory and real-world applications of graph width measures and notions of structural sparseness;
- verification techniques for emerging paradigms such as probabilistic, neural and quantum programming;
- application of machine learning and NLP to software engineering problems such as program synthesis;
- deep learning for modelling, classification, and autonomous control.

EDS strategy. EDS develops novel methods and systems for the computational analysis of data. A core ingredient is the exploitation of metadata, observations and measurements from large-scale information systems to ground testable theory, conduct experimentation and enable practical application of research outcomes, leading to demonstrable economic and societal impacts.

Since REF2014, we have published 140+ journal and 120+ conference papers, including in TPAMI (9 papers), IEEE TKDE(2), IEEE TIFS(2), IEEE TSC(2), JoCCH(2), Scientometrics(2), JASIST(2), TACL(2), PLoS One(3).

We have made significant advances in data analytics for Parkinson's disease, deployed in clinical trials in the UK, USA, Germany and Belgium and released as open-source software (Roussos, Weston); named entity recognition and sentiment analysis (Levene, Weston, Zhang); resource usage optimisation and real-time anomaly detection (Sotiriadis); data-driven cyber security techniques, receiving a Samsung research award (Yoo); a Fisher-Rao metric for curves using edge information (Maybank); topological patterns of network evolution characteristic of trustworthy actors (Provetti); deep neural network techniques for predicting human protein function (Wan).

Over the next five years EDS will focus on:

- modelling social and human dynamics employing spatio-temporal probabilistic models;
- disease progression assessment using mobile and wearable devices;
- deep learning methods, with biomedical, cloud computing and security applications;
- applications of NLP in sentiment analysis, named entity recognition, and distributional representations of language.

BIDA strategy. Through its network of collaborations and external partnerships, BIDA provides a vibrant environment for a next generation of data scientists. Collaborations are often conceived through BIDA's regular workshops, convened to explore cross-disciplinary perspectives on specific topics and challenges. New collaborations have been forged with Geography and the British Geological Survey to develop computational models of coastal erosion using IoT smart sensor data; with the Institute of Criminal Policy Research (funded by the Dawes Trust) to investigate user signals in social media communications for evidence-gathering in criminal prosecutions; and with a market branding company to develop an NLP system for matching journalistic articles and Twitter data.

Over the next five years BIDA will:

- develop data-driven methodologies to address big data and scalability challenges arising in the sciences;
- collaborate with researchers in social sciences, arts and humanities to exploit the potential of advances in text mining, data curation and user modelling;

- spearhead public debate on ethics and emerging technologies such as video surveillance, user profiling and AI in general.

BKL strategy. BKL research has focused on the challenges of designing software to support users' knowledge creation processes. We have forged new collaborations with the British Library, British Museum, and educationalists from several European universities and secured joint funding leading to intelligent tools to support exploratory learning (EU), a specialist knowledge base to support museology scholars' research (AHRC), and further development of the Samtla statistical language modelling software for searching digital archives (Wellcome Trust ISSF) – ranked second in the 2018 British Library Labs Competition.

Over the next five years BKL will:

- apply cutting-edge computer science to co-design tools that support domain experts in data integration, analysis and visualisation and in creating and sharing knowledge;
- collaborate with educationalists, psychologists and practitioners to exploit the potential of AI in providing personalised support for learners and tutors in open-ended learning settings.

1.3 Impact strategy

Review of REF2014 impact strategy. As stated in our REF2014 impact narrative, we have encouraged “collaborative research carried out by multidisciplinary teams involving user stakeholders” (cf. Impact Case Roussos-LondonAmbulance), promoted “links with industry partners with whom we can develop research exploitation routes” (cf. Case Study Kontchakov-VKG), engaged “with commercial, educational and policy organisations in knowledge transfer activities” (cf. Case Study Roussos-ITU), and maintained “department-industry networks through our part-time postgraduates and alumni”.

Post-REF2014 strategy. Following REF2014, the Department reassessed its approach to generating impact and put in place additional initiatives and structures to enhance it. Our approach is based on five key principles, which will continue to drive our strategy over the next five years:

- (I1) Embed impact within our strategic research directions and research processes.

For example, EDS employs an experimental systems approach leading to the development of novel software in healthcare and smart cities (cf. Case Studies Roussos-LondonAmbulance, Roussos-ITU). KRDM develops data management theories and technologies working with end-users in industry (cf. Case Study Kontchakov-VKG).

- (I2) Develop impact-generating activities through interdisciplinary and industrial collaborations (see Sec. 4).

- (I3) Recognise the importance of impact in our recruitment strategy by hiring staff with world-leading research developed collaboratively with industrial users.

- (I4) Leverage our unique relationship with research students: due to Birkbeck's distinctive mission, we are uniquely positioned to collaboratively address economic and societal challenges identified by our students, the majority of whom pursue research concurrently with their professional careers.

For example, our work on intelligent tools for ambulance routing (Case Study Roussos-LondonAmbulance) drew on the experience of part-time PhD student Marcus Poulton at the London Ambulance Service; and our collaboration with Neo4j on advanced querying

methods for graph databases was facilitated by Petra Selmer, who completed her PhD part-time at Birkbeck while working for Neo4j.

- (15) Communicate the outcomes of our research through a full breadth of non-academic routes, both digital and in-person.

These initiatives are supported by structures and measures including:

- **Department's Academic Lead for Impact**, who promotes and monitors the implementation of impact strategy and achievement of impact, and ensures that impacts are recorded and communicated, building a knowledge base of external stakeholders and partners to inform future planning.
- **Department's Industry Advisory Board (IAB)**, comprising senior IT professionals from UK/global corporations in sectors such as innovation, consultancy, web/mobile technologies, ed-tech, energy, telecommunications. IAB members advise on all aspects of research to ensure relevance to economic and societal challenges, and serve as mentors supporting the development of collaborative activities as per (12).
- **School's Research Impact Officer (RIO)**, a full-time role in BEI with the remit of evaluating and enhancing impact, working closely with other professional staff of the School and College (public engagement, research development and support, alumni, business services, communications). When new staff join the Department they meet with the RIO to discuss the impact potential of their research. Staff preparing research funding proposals consult with the RIO to ensure that impact is fully developed and embedded. The RIO meets regularly with the department's Academic Lead for Impact and the RIOs of other Schools, allowing us to benefit from and inform best practice and wider impact strategy across the College.
- **School and College Impact funding**, available to amplify the impact of ongoing research (see 3.1).

Areas of impact. Following this approach, we have substantially increased our impact on the IT, healthcare, culture and urban development sectors, as well as now impacting on digital humanities, cyber security and linked data management (see 4.2).

1.4 Research integrity and open research environment.

The Department is committed to professionalism, openness, exercise of independent thought and application of ethical principles, aligning with Birkbeck's Research Integrity and Open Research Data policies and concordats.

BIDA leads Birkbeck's research on ethical issues in emerging technologies, and is the public face of the College in the debate on the deployment of AI in our societies. All staff and research students undertake mandatory ethics training before commencing their research at Birkbeck.

We operate a rigorous process for reviewing the ethical aspects of research involving human participants, proposed by staff or students. The review is coordinated by the Department's Research Ethics Officer (REO) who passes non-routine cases to the School or College Ethics Committee. The REO works with researchers to incorporate additional safeguards if required. The REO serves on the School Ethics Committee, which has oversight of all ethical reviews in the School and runs regular workshops to ensure that researchers are fully apprised of the College's principles and policies on research ethics and research integrity. Departmental REOs undertake mandatory training before being appointed.

Our department's PhD students played an active role in organising the Bloomsbury colleges' "Love Data Week" for research students in 2018 and 2020, discussing research data

management and ethics.

Wherever possible we encourage staff to publish open-access, if necessary supplementing funding available for this from the College. All articles accepted for publication are deposited in open access form (Green or Gold) in the Birkbeck institutional repository BIROn. We extensively use open publishing services such as arXiv (260+ papers since REF2014).

We use github, dedicated Web pages and the Birkbeck Data Repository BiRD to make all software and data produced by our research freely available, compliant with regulatory frameworks and data protection legislation. For example, the code for the Virtual Knowledge Graph system Ontop is available at <https://github.com/ontop/ontop> and for the Parkinson's PDkit at <https://github.com/pdkit/pdkit>, the ontology developed by the Weaving Communities of Practice project at <https://www2.bbk.ac.uk/weavingcommunities/Ontology/>, the Mapping Museums data and software at <http://museweb.dcs.bbk.ac.uk/data> and <https://github.com/MappingMuseums/MMWebApp>.

2. People

2.1 Staffing Strategy and Staff Development

Mentoring, Probation, Appraisal. Academic and research staff are assigned to one of the research Groups as their primary affiliation, providing peer support alongside a research Mentor who advises on research career development, training, funding applications and forging collaborations with other institutions/disciplines. Staff meet as required, but at least annually, with their Mentor.

Probationary staff meet annually with their Probationary Advisor to review all aspects of their work. Post-probation academic staff undertake an annual Academic Review with a senior colleague appointed by the HoD (Levene) to discuss achievements in the previous year, objectives for the coming year, career aspirations, promotion planning, balance of work, and any obstacles to progress in research, teaching or academic management. Research staff undertake a similar review, tailored towards their career stage.

Training. The Department's staff undertake College training in diversity and equality, unconscious bias, recruitment, line management, research supervision (for both new and experienced supervisors), promotion, data protection, writing grant proposals, project management, open access, public engagement and knowledge exchange, aligned with the relevant policies and concordats. This provides a structure supporting the more informal coaching through mentorship within the Department.

Staff undertake training organised by the School in publishing research, generating impact, research integrity and ethics, using audio-visual media for research communication (supported by the BEI Film Unit and the Derek Jarman Lab), and applying for research funding – including events where senior officers from specific funding bodies are invited to speak directly to staff.

The Department's Knowledge Exchange champion organises regular training in commercialisation, delivered by external experts. New staff attend innovation and entrepreneurship training delivered by UCL Enterprise.

Workload allocation. Academic staff have a standard annual teaching load determining the amount of lecture/lab-based teaching, tutoring and BSc/MSc project supervision. Allocation of teaching duties is undertaken by the HoD in discussion with the individuals and the Directors of Studies. Management duties are also shared evenly, fostering academics' engagement in College, School and Departmental processes. Most are rotated every three years and, as with teaching, individuals discuss their preferences with the HoD. There are reductions for ECRs (see below).

To promote transparency, everyone's duties are published annually on the departmental intranet.

Research Grants, Impact. The School's Research Development Officer assists staff in developing new research collaborations and proposals, and oversees a formal peer review process for all funding proposals. The School's Research Impact Officer assists staff in developing impact from their research (see 1.3). The Department's academic lead for impact (Zakharyashev) and Knowledge Exchange champion (Roussos) work with individuals and the Research and Impact Officers, articulating with the School's and College's training and support mechanisms.

The College's Research Office provides support for submitting proposals and communicating with external funders. It advises on IP protection and exploitation, supported with specialist Tech Transfer expertise from UCL Business.

The School provides funding for pump-priming the research of new staff and new collaborations (School Research Fund) and for supporting staff in developing impact from their research (School Impact Fund). Applications can be made several times each year and are assessed according to quality and strategic importance by the School's Executive Board. Academic staff can additionally apply to College funding calls e.g. College Impact Seed Fund, Wellcome Trust ISSF.

Sabbaticals. Academic staff (including fixed- and part-time) can take one term in ten as a Research or Impact sabbatical. They are required to report back on how they have used this leave and the outcomes achieved.

ECRs. The teaching duties of ECRs are kept below the departmental average, starting at a half load and increasing gradually to a full load by the third year. ECRs have a lighter management load throughout their first three years, taking on roles with coordination and decision-making responsibilities appropriate for their career stage. Research Mentors, the Director of Research and HoD provide guidance on all aspects of research.

The effectiveness of our support of ECRs is evidenced by the promotion during this census period of seven lecturers to SL and two to Reader.

PDRAs contribute to the Department's vitality through activities such as helping to organise conferences/workshops/seminars, running stakeholder events, producing research software/datasets, preparing online research-related content, presenting at conferences, and undertaking research-related visits. They are offered opportunities to guest lecture on taught modules, supported by their line manager and the Department's Teaching Tutor.

The effectiveness of our support for PDRAs is exemplified by the career trajectories of two colleagues who joined as PDRAs and were then successful in being appointed to a Lectureship, with subsequent promotion of one to SL and one to Reader. Three other PDRAs have progressed to Lecturer/SL positions at other HEIs during this census period; four have progressed to senior R&D posts in industry.

Staffing and recruitment. The College's recruitment strategy focusses on appointing mainly at Lecturer level. The new academics we appointed since REF2014 (see below) are demonstrably meeting our research and impact strategy principles R1, R4, R6, I1-I3, as evidenced by their research expertise, publications quality, extensive collaborations and impact. Most academic posts are open-ended although on occasion there are fixed-term posts associated with specific initiatives; to date, all our fixed-term post-holders have been transferred to open-ended contracts towards the end of probation.

Since REF2014 we have appointed 8 Lecturers (4 early-career), one SL, one Reader (four

are BAME, all are male, women were shortlisted for seven of the posts).

The Department grew by 30% over this census period and now comprises 8 Professors, 3 Readers, 7 SLs and 8 Lecturers, showing an even balance between senior and junior grades. In recognition of the strength of our strategy, the College has announced three more posts for 2021: one Professor, two SL/Readers. We are actively addressing gender imbalance through the measures outlined in 2.3.

A steady rate of staff promotions facilitates **succession planning** as more senior management roles (including research leadership roles) can be prepared for through discussions, facilitated by the HoD, between current holders and staff seeking promotion, and handed over after promotion. Female staff benefit from the College's Aurora Leadership programme.

Space. The Department works with College Estates to provision high-quality premises for researchers. Full-time academics are allocated their own office. Part-time academics, research staff, and full-time research students are assigned their own desk and PC in a shared office/lab. Part-time research students are assigned a shared desk and PC. There are three dedicated Research Seminar and Meeting rooms, and additional ones bookable throughout the School. The department's labs have ample capacity to be booked for user design/evaluation workshops and community engagement/dissemination events. Additional study and social space is available in the BEI Graduate Centre.

Recognition of research and impact. Appointment, promotion and remuneration processes recognise all aspects of research, including outputs, grants, supervision, public engagement, knowledge exchange, impact, community service. To reward successful grant applications, a small proportion of the grant overheads allocated to the Department is available to the award holder(s) to fund research-related expenses. Research achievements are publicised on the Department's website, ensuring visibility, providing inspiration for early-career researchers, and creating a benchmark for expected levels of activity.

Research Exchanges. The Department provides generous financial support for conference attendance and research-related visits: see 3.1,4.1.

Retention. We have high academic staff retention, with just three leavers in this census period.

Implementation of the Concordat to Support the Career Development of Researchers. As detailed above and in 2.2 and 2.3, we espouse the three Principles of the 2019 Concordat by providing a supportive and inclusive working environment, recognising and valuing all researchers' contributions, and fostering researchers' professional and career development. Our provisions are under continual review by the Department's management and research committees.

2.2 Research Students

Recruitment. The Department's research student recruitment strategy leverages our research reputation to attract strong applicants. Aligning with Birkbeck's mission, the majority enrol for part-time study and have significant other commitments. Student recruitment levels rose in the latter part of the previous census period and have been maintained throughout this period, with 45 students enrolled during 2019/20 (62% PT, 38% FT). We recruit applicants from diverse backgrounds, as evidenced by our current research student demographics: 40% BAME, 40% non-British, 25% female, 12% registered disabled. Staff involved in research student recruitment are required to have undertaken recruitment training.

Research Studentships. The Department has funded 14 PhD studentships in this census period, awarded to exceptional part-time or full-time applicants. Additionally, 2 students have

been funded by College interdisciplinary studentships, awarded from time to time through institution-wide competition. Birkbeck staff can also apply for collaborative PhD studentships in the annual Bloomsbury Consortium PhD Studentships competition: we have been successful in 4 such bids in this period, two in collaboration with UCL IoE and two with LSHTM.

The Department also has 4 Graduate Teaching Assistant posts whose holders complete a PhD over four years, with full fee remission, while contributing to the department's teaching and enhancing their transferable skills.

Support and Monitoring. We implement, and in some areas go beyond, the College's Code of Practice for Postgraduate Training and Research. Each student is assigned one or two primary supervisors with expertise in their research area, and a secondary supervisor for a broader perspective. Less experienced supervisors are teamed with staff who have strong supervisory track records. Female students may request that one of their supervisors is female. Full-time students meet weekly with their supervisors, part-time students every fortnight. The Research Tutor oversees students' well-being, induction and training, organises termly meetings with all students and an annual survey. Three seminar series, specialist discussion/reading groups, research group/centre meetings and annual Research Days provide students with a range of opportunities to integrate into the research life of the department and present their work in informal settings.

We make special efforts to create opportunities for part-time students to meet with staff and other students. All training events for research students are held in late afternoon/evening.

A subcommittee of the Department's Research Committee monitors students' progression, training needs, transfer to PhD, and completion. Students submit written reports annually and give oral presentations at key stages.

There has been a 10% increase in the number of PhDs awarded in this census period compared to the last. In the Department's last research student survey, 90% stated they were satisfied with their supervision and 88% with the progression processes.

Skills Development. All students attend the Department's Research Methods training and generic skills training organised by Birkbeck's Graduate Research School and the Bloomsbury Postgraduate Skills Network. Most College training courses for staff are also open to research students.

The Department funds students' presentation of papers at conferences – at least one paper per year, for both PT and FT students.

Research students are offered opportunities to provide teaching assistance on our taught programmes and receive training for this organised by the College and support from the Teaching Tutor.

The effectiveness of our research student support and training is evidenced by the career trajectories of our PhD graduates, e.g. in this census period five attained Lecturer positions at HEIs, two exploited their doctoral research to co-found new start-ups, and four were appointed to R&D posts in areas such as medical informatics, data science and software services.

2.3 Equality and Diversity

Strategy to support equality and diversity

For all posts we encourage applicants with **diverse backgrounds**, as evidenced by our current staff demographics: 6 academic/research staff are BAME, the majority are of non-British origin, two are women. For new female academic/research staff, we ensure that at least one of their Probationary Advisor or Mentor is a woman.

All categories of staff are required to undertake **Equality & Diversity** and **Unconscious Bias training**, and to repeat this every three years. Staff involved in recruitment are required to have undertaken **recruitment training**, which includes an equalities component. Staff recruitment panels contain at least one woman.

The HoD supports staff preparing to **apply for promotion, accelerated increments** and **performance-related payments**, which are open to all staff categories. Staff are also encouraged to attend the College's workshops on applying for promotion.

A **positive review of promotions** is undertaken annually by a panel comprising the HoD and senior professors (4 men, 1 woman) to identify staff to encourage to apply. Mentors and academic reviewers also play a proactive role in this respect.

The Department engages with the College's and School's **equality and diversity** initiatives and with the Action Plan of the HR Excellence in Research Award, working with the School's Assistant Dean for Equality & Diversity to embed these in all its processes.

We have a staunch commitment to **Athena SWAN**: Poulouvassilis was a member of the College's Athena SWAN Committee from its inception till 2017 and participated in the successful application for Bronze in 2016. Roussos led the Department's Athena SWAN Self-Assessment Team preparing the successful application for Bronze in 2017. Poulouvassilis is a Mentor in the Aurora Leadership Programme. Our annual Andrew & Kathleen Booth lecture attracts leading innovators and alternates a female and male distinguished speaker each year.

The Department's staffing capacity enables **sabbatical leave** to be accommodated as part of normal workload planning. All staff categories are entitled to **parental/caring** leave according to College policies, and their duties are covered by recruiting additional staff for a fixed period.

Due in part to Birkbeck's teaching being largely in the evening, the Department has a longstanding culture where **flexible working** is the norm for all staff. Options include homeworking, staggered hours/flexi-time, part-time and job-share. Evening teaching for academic staff does not exceed 3 evenings per week and is balanced by late morning starts.

Remote working (including remote teaching during the COVID-19 pandemic) is enabled by extensive IT infrastructure allowing remote access to all resources. Staff and students are also supported through licensing software and loaning hardware for home use.

In the last Departmental survey, 96% and 88% of staff endorsed the Department's flexible working and family support, respectively. In the last College survey, 89% of the Department's staff agreed that they work in an inclusive and enabling environment promoting tolerance and freedom from discrimination.

Career pathways. Part-time staff have the same opportunities and entitlements as full-time, with pro-rata allocation of work duties. Fixed-term staff have the same opportunities and entitlements as those on open-ended contracts. Announcements of job openings are regularly emailed by HR. PDRAs approaching the end of their contract meet with their line manager to discuss continuing work opportunities. Bridging funding is available for PDRAs between contracts.

Research Leadership roles. The Director of Research (Zakharyashev), Director of BIDA (Provetti) and Director of BKL (Poulouvassilis) are appointed by the HoD in consultation with the Dean and senior staff. Research Group directors are appointed by the HoD in consultation with the Director of Research and Group members. The departmental Research Committee is chaired by the Director of Research. Its core members include the Research Tutor, Group and Centre directors, and elected representatives of the research staff and students. However, all

are encouraged to attend its meetings and participate in the formulation of research and impact strategy, and the setting and monitoring of objectives.

Access to funding. All academic and research staff and students can apply to the Department for funding to attend conferences, undertake research-related visits, attend training courses, and organise stakeholder workshops and dissemination events. All staff have access to the same support mechanisms in preparing applications for School, College and external funding (see 2.1).

Returning from leave and changing circumstances. Our flexible working provisions enable staff to manage transitions after returning from periods of parental leave or ill health, changes in their health or caring responsibilities, and switching between full- and part-time working. Staff returning from leave may request flexible working or a variation in their contract (including homeworking, staggered hours/flexi-time, part-time, job-share). Changes to working arrangements are managed flexibly between the individual and their line manager. Research students can similarly switch between full- and part-time study and can request breaks-in-study to accommodate changes in their professional or personal circumstances.

Routine planning for periods of maternity, paternity, shared parental and adoption leave includes a detailed leave planner and planning for Keeping in Touch (KIT) days. Staff on maternity/adoption leave can take up to ten paid KIT days. Upon return to work, staff are supported with childcare costs through Birkbeck's childcare vouchers scheme. Returning staff and students have access to the College's nursery, which operates 5.30-9pm when most teaching and supervision takes place.

Support for those with disabilities. The Department's Disability Officer liaises with the College's Disability support services to ensure that support plans are collaboratively formulated with staff and students to enable them to work and study effectively. This includes access to disability allowances and learning support funds, provisioning of assistive technologies, and adjustments to working environments, work duties and required presence in College. The Disability Officer is a member of the School's Disability Working Group.

Wellbeing of staff and students. The HoD operates an open-door policy as do all academic and professional staff (virtual during the COVID-19 pandemic). The Department has a code of practice governing responsiveness to emails and requests for meetings. So staff and students are easily able to obtain advice on College, School and Departmental policies, support mechanisms and resources.

We place strong emphasis on integration and communication across the department. This is ensured through regular research group/centre meetings, three seminar series, training events for staff and students, and a monthly departmental "Merienda" where we celebrate the past month's achievements. There are two annual social events, the Christmas party and the Away Day in September. In the last College survey, 88% of the Department's staff agreed that Birkbeck is a good place to work.

Consideration of Equality and Diversity in construction of REF submission. Our departmental REF preparation team (3 men, 1 woman) read and recommended outputs and impact case studies for our UoA. The selection of outputs and impact case studies was undertaken by a School-level panel chaired by the Dean and including the School's three UoA leads, Deputy Dean, Assistant Dean for Research and one external expert (5 men, 2 women). The College's code of practice was followed throughout, including a three-round process for outputs selection. After each round the College undertook an analysis of the distribution of outputs across staff with respect to multiple protected characteristics and no statistically significant imbalances were found for our UoA.

3. Income, infrastructure and facilities

Our 30% growth in staff since REF2014 has been accompanied by a strategic aim to increase research resources in terms of income (both external and internal), office and lab space, and high-performance computing. It is to be noted that we undertake significant amounts of fundamental research for which additional external funding is not required.

3.1 Research funding

The Department has three main sources of income to support its research strategy: (i) external funding from research councils, foundations and trusts; (ii) internal funding from the School and College; (iii) OfS through our IoC participation.

External grants. External awards have grown by 50% from £1.6M in the previous REF period to £2.4M in the current period. Major awards include:

- KRDM: the EPSRC LIQUID grant on data integration (£89K) and the EPSRC iTract and quad^{MD} grants on OBDA (£354K, £453K), leading to impact case study Kontchakov-VKG and major publications in JACM, AIJ, JAIR, LICS, PODS;
- EDS: an M.J.Fox Foundation grant to develop a data science toolbox for Parkinson's disease (£114K), an Innovate UK grant to develop the cloudUPDRS app for Parkinson's sufferers (£69K), and funding from the Bloomsbury Consortium and Wellcome Trust ISSF to investigate the IoT's role in giving agency and voice to individuals and communities (£78K); leading also to publications in IEEE Access, J. Ambient Intelligence & Smart Environments, J. Pervasive Mobile Computing, PerCom, eHealth 360°;
- AVS: three EPSRC grants on risk measurement (£101K), probabilistic verification (£100K), and stability in graphs (£152K), leading to publications in TCS, IJAR, J. Comb., J. Comb. Theory, POPL;
- BIDA: UKRI GCRF Action Against Stunting Hub funding (£195K), developing data analysis techniques to investigate the causes of child stunting (still in early stages);
- BKL: EU iTalk2Learn project (£326K) on intelligent support for 5-11 year olds' learning of maths, and AHRC Mapping Museums project (£215K) developing a specialist knowledge base for museology scholars and professionals; leading also to publications in ACM JoCCH, UMAP, EC-TEL, LAK.

Internal grants. In this census period we were awarded School funding of £110K for pump-priming research projects, £83K for impact development (impact case studies Roussos-LondonAmbulance and Roussos-ITU were supported by a series of such grants), £30K for conference attendance, as well as £50K from the College's ISSF, Impact Seed Fund and NYU Collaboration Fund. The Department additionally provided £102K to staff and students attending conferences and undertaking research-related visits. Thus, internal research funding amounts to over £375K.

IoC grants. The IoC awarded us over £600K to develop new UG/PG programmes in Data Science. This was a significant boost to our Data Science and Algorithms research as it funded 50% of three new academic posts. A PGCert was developed with the British Library and National Archives to provide digital skills training for their staff, building on and extending our research collaborations in the Samtla project. We secured additional OfS funding of £100K to develop a new PGCert in Applied Data Science, funding 50% of a further post. The IoC funds also Birkbeck's IoC Manager who contributes to Samtla and NLP research at the BKL. IoC membership also enhances our environment through initiatives to widen participation in under-

represented groups; for example, we were awarded £120K in scholarships funding for women and black students on the new PGCert.

Future funding. Continuing to increase external funding, from a broad range of sources, is a key aim. We are currently preparing 7 proposals for EPSRC funding, 2 BBSRC/MRC proposals in life sciences informatics, 2 AHRC/ESRC proposals in digital humanities and museum data analytics, and 4 InnovateUK proposals in healthcare data analytics, blockchain analytics, construction sensor data analysis, and computational journalism. Two proposals (EPSRC, AHRC, £500K) have already been funded in 2021.

3.2 Research infrastructure

The Department works with the College's Estates, ITS and Library to ensure provision of high-quality space, general IT and learning resources for its researchers.

BIDA's foundation was in part a response to the REF2014 outcomes which recommended that the College invest more in interdisciplinary research and the research environment. BIDA is physically distributed across labs/offices of the participating Schools. Due to its research reach and the strategic significance it has established, the College is currently elevating BIDA to become one of Birkbeck's eight Research Institutes, which will lead to increased college funding, support, and collaboration opportunities.

Since its launch in 2016, **BKL** has been housed in a purpose-built lab for 20+ researchers and its membership has expanded to include researchers from Birkbeck's departments of Psychology, History of Art and Cultures & Languages.

Computing facilities. The Department provides the hardware, software and technical training required by all staff and students to undertake their research. In addition to equipment purchased for specific projects, we have a SLURM GPU cluster with 12xP100 and 16xGTX1080i GPUs. Virtual machines for R&D are provisioned on our Xen hypervisor pool (16 servers, 480 physical cores, 2.8TB RAM). We also have a Rocks cluster of six compute nodes and two further general-purpose computing servers (AMD EPYC). For storage we use two Read Intensive RAID arrays (2x9TB PCIe SSD) and a dedicated storage server (Open-E DSS) with 22TB SSD disk. Inter-host networks are 10Gbps or faster. Our teaching labs can be booked for user and community engagement events; when they are not in use we re-utilise the machines for research as a HTCondor pool with 1248 compute slots and 2TB RAM. Since REF2014 we have doubled our average spend on research computing to £40K per annum.

Research Support Staff. The department's research is supported by two Systems and one Administrative staff FTEs. In addition, three School staff FTEs – the Research Development, Impact, and Finance Officers – manage the School's research processes and support departments' research development and exploitation. The School's Communication Officer and Event Officer support our research communication activities. Additional expertise and support is provided by the Department's academic lead for impact and Knowledge Exchange champion, the Research Office, and UCL Business (see 2.1).

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

To achieve our strategic aims we collaborate with leading computer scientists, researchers from other disciplines, and user stakeholders beyond academia. In particular, we

- promote collaboration by inviting leading researchers to visit Birkbeck and supporting visits in the other direction;

- encourage and support staff in initiating joint projects with other university and industrial partners, including multi- and interdisciplinary research;
- promote knowledge exchange, public engagement and impact by organising stakeholder workshops and dissemination events.

4.1 Research collaboration

The Department runs weekly seminars where leading scholars from the UK, Europe and beyond present their research to staff and students. Approximately 100 seminars took place over this census period, often combined with additional activities within specific research groups. BIDA and BKL run additional interdisciplinary seminar series, with approximately 50 events during this period.

50+ researchers visited us during this period from universities in 18 countries, while staff undertook 100+ visits to universities/organisations in 21 countries. The Department contributed to funding longer-term visits of 20+ researchers from other universities/organisations to Birkbeck and 35+ such visits in the opposite direction.

We have held Visiting Professorships at the Northwestern Polytechnical University, China, and University of Technology, Australia (Maybank); Bar-Ilan University (Levene); KAIST and University of Sydney (Yoo); Higher School of Economics, Russia (Zakharyashev). Zhang is currently on a two-year leave of absence as Staff Research Scientist at Blue Prism AI Labs exploiting his expertise in machine learning.

Articles published since 2014 have co-authors from 80+ universities in 30+ countries, making our research truly international. We have co-authors from 35+ companies including Alibaba, BNY Mellon, BT, IBM, Microsoft, Neo4j, Paddy Power, Samsung, Siemens, Telefonica Digital.

Most of our funded research projects are in collaboration with colleagues from other universities in the UK and internationally, many from other disciplines, and with other stakeholders. For example,

- in KRDM, the OBDA projects are joint with the universities of Liverpool, Bozen-Bolzano and Sassari, and with Siemens (Germany), Sirius (Norway), Siris Academic (Spain), and the Pilsudski Institute of America;
- in EDS, one project is collaborative with University of the Arts, Proboscis and British Antarctic Survey; another is with UCL IoN, Benchmark Performance, Retechnica and Audience Focus;
- in BIDA, the new £19.76M UKRI GCRF project involves researchers from multiple science and social science disciplines affiliated with 18 institutions in the UK, India, Indonesia and Senegal;
- in BKL, the Mapping Museums project is collaborative with Birkbeck's History of Art department and stakeholders from across the UK museum sector (including Arts Council England, DCMS and the Museums Development Network); the Samtla project with the British Library, Wellcome Trust, and SOAS; and the iTalk2Learn project with educationalists from several European universities.

We frequently supervise students jointly with other departments and Bloomsbury Consortium Institutions: in this census period two students with Psychology (one MRC-funded, one College-funded), a College-funded student with Biology, and four Bloomsbury Consortium-funded students – two with UCL IoE, two with LSHTM.

In addition to BIDA and BKL, staff are members of several other research centres, including the Centre for Cognition, Computation & Modelling, Centre for Innovation Management Research, Institute of Structural and Molecular Biology, and Centre for Educational Neuroscience.

4.2 Impact beyond academia

Through implementation of our post-REF2014 impact strategy, our network of research users and beneficiaries has expanded substantially during the census period:

- In **Healthcare**, EDS has pioneered research into data-driven techniques to reduce ambulance arrival times, incorporated into decision support tools deployed by the London Ambulance Service (Impact Case Study Roussos-LondonAmbulance). In collaboration with clinical and commercial partners, we developed cloudUPDRS, the first smartphone app certified as a Class I medical device by the Medicines and Healthcare Products Regulatory Agency for assessing the motor symptoms of Parkinson's disease. We are developing a secure platform for healthcare data analytics with Cambridge Medical Academy.
- In **Information technology**, KRDM has made significant contributions to the development of theory, practice and tools for OBDA, collaborating in the development of the Ontop platform with start-up Ontopic (Italy) and other partners as listed in 4.1 (Impact Case Study Kontchakov-VKG). We have secured funding from the European Space Agency to develop conceptual modelling-based techniques for data exchange between ESA and their suppliers of satellite and rocket technology.
- In **Smart cities**, Roussos is Associate Rapporteur of Study Group 20 of the International Telecommunications Union (ITU), developing standards in service interoperability and big data analytics for smart cities. He has led research into integrating diverse technologies into a comprehensive system of smart city universal entity identification, ratified as ITU Recommendation Y.4805 and providing a blueprint for smart cities in China and several African countries (Impact Case Study Roussos-ITU).
- In **Cyber security**, we have developed a data-driven cyber-intrusion detection platform in collaboration with KAIST, used at Samsung and BT. We are working with Samsung on next-generation monitoring and protection systems for IoT-enabled devices, and with a market-leading blockchain technology company on identifying abnormalities in blockchain data.
- In **Linked Data standardisation**, Hidders co-leads the Property-Graph Schema Working Group of the Linked Data Benchmark Council (LDBC). He is coordinating researchers and companies such as Neo4j, Amazon Neptune and Google to standardise the Property-Graph data model as LDBC's representative on the international SQL Standard committee (ISO/IEC JTC1/SC34/WG3). The PGSWG is developing the GQL query language for graph data, to be incorporated also into SQL.
- In **Digital Humanities and Cultural Heritage**, the Samtla software has been deployed over the British Library historical text archive and Wellcome Trust Medical Library. UK museum organisations are using the Mapping Museums knowledge base to understand the current state of the sector. We are working with leading science museums including the Science Museum, London, and the Exploratorium, San Francisco, to develop audience research methods incorporating high-precision indoor location sensing and spatial analytics.

As shown by the above, our research focuses on timely technological and societal problems. Most recently, the Covid-19 emergency led several staff to initiate projects aimed at understanding and mitigating the effects of the pandemic: Poulouvassilis obtained collaborative funding with History of Art and Geography from the UKRI Covid-19 Rapid Response Call to investigate the resilience of UK museums during the crisis; Levene and Weston are collaborating with doctors from two London hospitals to develop a machine learning model for diagnosing Covid-19 from patients' medical social media posts; Provetti is collaborating with Philosophy to explore privacy issues arising from Covid-tracking apps.

4.3 Wider influence

We have served on the **Editorial Boards of 30+ journals**, including Artificial Intelligence, ACM ToCL, J. Applied Logic (Zakharyashev), IEEE Transactions on Sustainable Computing, J. Big Data Research, IEEE Communications Letters (Yoo), Pervasive and Mobile Computing, IEEE Transactions on Technology and Society, IEEE Transactions on Big Data (Roussos), Computing and Informatics, International J. Computer Vision (Maybank), Applied Intelligence, Informatics, Open Journal of Information Systems (Magoulas), IEEE Transactions on Knowledge and Data Engineering (Poulouvassilis).

We were **General or Programme Chairs of 23 international conferences and 10 international workshops**, including RuleML+RR (Kontchakov), BICOD (Poulouvassilis, Cali, Wood), IEEE Int. Symposium on Smart Learning for the Next Generation (Yoo), IEEE PERCOM (Roussos), Symposium on Parallel and Distributed Computing, Int. Conf. on Information, Intelligence, Systems and Applications (Sotiriadis), Int. Symposium on Intelligent Data Analysis (Weston), IEEE/WIC/ACM Web Intelligence (Zhang), BeyondMR@SIGMOD (Hidders).

We **organised at Birkbeck** the RuleML+RR 2017 Conference (Organisation Chair Kontchakov) and the BICOD 2017 Conference (Organisation Chair Martin) and served on **250+ other conference/workshop programme committees**.

We have served on **10 Steering Committees**, including RR (Kontchakov), TACL, AiML (Zakharyashev), BICOD (Cali, Poulouvassilis), FSCD (Fuhs), IDA Society (Weston), BeyondMR@SIGMOD (Hidders).

We have given **15 invited Keynotes**, including at the 12th Int. Conf. on Flexible Query Answering Systems, 14th Int. Conf. on Formal Concept Analysis (Poulouvassilis), 11th Computer Science and Electronic Engineering Conf. (Roussos), 28th Conf. on Information and Knowledge Management (Maybank), 8th Hellenic Conf. on Artificial Intelligence, 6th Conf. on Information and Communication Technologies in Education (Magoulas), 8th Danish Static Analysis Symposium (Fuhs).

We have given **invited lectures/courses at 10 Summer Schools**, including EDBT (Poulouvassilis), Reasoning Web (Kontchakov, Ryzhikov, Zakharyashev), International School on Rewriting (Fuhs), Probabilistic Model Checking (Han), ESSLLI (Zakharyashev), Data-Driven Incident Management (Yoo).

Staff have been **external examiners of 75+ PhD theses**, 50+ in the UK and 25+ overseas.

We have published 3 authored **books** (Wan, Hidders, Roussos), 7 encyclopaedia articles (Hidders, Poulouvassilis, Wood), and co-edited the proceedings of 15 conferences.

Our **professional services** include contributions to industry and open-source projects in software engineering, information management, and information retrieval; training events with the British Library; a video on data visualisation for a Publisher; advising Arts Council England on data collection strategy; advising on IoT legislation through the ACM Public Policy Committee.

Panels: Staff have served on 4 EPSRC Prioritisation panels, 4 Horizon-2020 panels, research funding panels for the Academy of Finland and Research Council of Norway, and as reviewers for funding bodies in 20+ countries across Europe, Asia and America. Poulouvassilis served on the REF2014 Subpanel for Computer Science & Informatics and participated in two EPSRC ICT Theme Delivery Workshops.

Fellowships/Memberships: Maybank is Fellow of the Institute of Mathematics and its Applications, the IEEE, and the Royal Statistical Society; Poulouvassilis BCS Fellow; Yoo Senior Member of the IEEE and Member of two IEEE Technical Committees; Fuhs Member of IFIP Working Group 1.6 on Rewriting; Magoulas Honorary Fellow of the Hellenic AI Society.

Awards: We received the EATCS-IPEC Nerode Prize 2020 (Razgon), ACM-PODS A.O.Mendelzon Test-Of-Time Award 2019 (Cali), ICDT-2017 Best Paper award (H.Chen), SIGIR-2017 Best Paper Award Honourable Mention (Zhang), Semantic Web Journal 2016 Outstanding Paper (Kontchakov), 2014 Marco Cadoli Student Paper Prize at KR-2014 (Kontchakov, Zakharyashev).

Media: Our Web Search and Mapping Museums research was highlighted on the BBC; our collaboration with Samsung by Business Weekly; our work on AI by Prime Economy Korea; and on the IoT by New Scientist.

Community and public engagement: Provetti spoke on AI and research ethics at the Bloomsbury Data Week 2017, Birkbeck's Law on Trial Week 2019, and is a regular panellist at Royal Statistical Society meetings. Poulouvassilis engaged with several UK museum sector organisations during the design, evaluation and dissemination activities of the Mapping Museums project. Fuhs hosted the 10th South England Regional Programming Language Seminar, with 60+ participants. Weston spoke on cryptography at the ICSA Technology Conference 2016. Yoo spoke on data-driven incident management at the UK Defence Academy in 2019. BKL researchers took part in a Virtual World Tour on the Future of Work, invited by Germany's Federal Ministry of Education and Research.

Emeritus Reader Roger Johnson continues to serve as the department's Historian, writing articles publicising the work of Andrew and Kathleen Booth and others and co-authoring the National Museum of Computing's guidebook on HEC1 – the UK's first mass-produced computer that incorporated also the Booth Multiplier, used in billions of chips manufactured around the globe every year. Johnson is also the official Historian of IFIP; secretary of the BCS Computer Conservation Society, the world's largest computer history group, which includes organising a rolling programme of monthly lectures put out on YouTube; and a Trustee of the Board responsible for the replica of Alan Turing's Bombe at the National Museum of Computing.