Institution: University of East London
Unit of Assessment: 11 Computer Science and Informatics
1. Unit context and structure, research and impact strategy

1.1 Overview

The Computer Science and Informatics UoA is based in the Department of Computer Science & Digital Technologies, within the School of Architecture, Computing and Engineering at the University of East London (UEL) and supports internationally leading applied **research with a clear focus on knowledge transfer to government and industry**. We firmly believe the vital role of research in our academic life and support UEL's key strategic objective of increasing the economic, social and cultural impact on communities through our education, research & enterprise activities. Since 2014 the Unit has pursued the following strategic aims:

- Develop solutions for economic and environmental challenges [SDG Goal 9], while searching for opportunities of application and commercialisation
- Increase the income generation of external research collaborations and knowledge exchange projects
- Prioritise the recruitment of new staff who produce high-quality research in common with our focus of 'responsive' research and knowledge transfer
- Increase our research focus by extending our existing areas of strength – software engineering and cybersecurity – and to build two new research groups (Enterprise Computing group and Intelligent Systems group)
- Taking advantage of the School's diverse range of subject expertise and their synergy to conduct interdisciplinary impactful research
- Improve the impact and dissemination of our work

Despite our small scale, with 12.2FTE research-active staff members, increasing from 4FTE in our 2014 REF submission, we are pleased we have tripled the size of our research-active staff.

Research in the Unit has been structured around the following research groups:
- Secure Software Engineering [1]
- Enterprise Computing [2]
- Intelligent Systems [3]

These groups have a mentoring and peer support role rather than a formal management function and encourage inter-disciplinary research, mentoring of early career researchers and the collaborative supervision of research students.

Since 2014, our portfolio of funded research has grown to all-time high levels, with over GBP1.97M of newly announced awards in this period. We regularly publish the outputs of our research in top-rated conferences and journals. We have focused our internal and external funding to improve our research environment, supporting high impact public engagement events, sabbaticals, research support, journals and conferences, and equipment.

1.2 Research Strategy

Our performance in REF2014 (UoA11, 4% 4*, 33% 3*, 33% 2* and 30% 1*) was good considering it was our first submission with just 4FTE. Over the last seven years, the institution has invested in people, specialist resources, and research infrastructure, to enhance capabilities and ensure a supportive and sustainable research environment.

Informed by the feedback from our submission to REF2014, our research strategy during this period was adjusted to include the following:

- Build on our track record of excellence in cybersecurity that was recognised by the REF2014 panel as an area of strength, with the creation of the Secure Software Engineering group.
- Sustain the growth in important areas like cloud computing and artificial intelligence with the creation of two new research groups, the Enterprise Computing research group and the Intelligent systems research group.
- Use our expertise to develop solutions to economic and environmental challenges, as outlined in UN SDG Goal 9 of the Sustainable Development Agenda [16]. The outcome has been artefacts used for knowledge transfer with government and industry.
- Support the development of our new staff members through targeted investment, reduced teaching loads and mentoring.
- Enhance the research environment through internal investment in the recruitment of high-quality research students with PhD scholarships.

1.3 Plans for Research Support

To foster academic collaboration, a series of research seminars have been delivered by research-active staff members to inform teaching-focused staff and PhD students on their research and to stimulate internal discussion and collaborations across various research topics. PhD students were also invited to present their projects to get feedback and prepare for their annual reviews and PhD viva. To foster external collaboration, a range of guest speakers have been invited from industry and academia to deliver lectures and participate in networking sessions. Furthermore, we have regular input to the Department from our industrial advisory panel and we have recently appointed a senior industrialist as a Visiting Professor, Lex Coors from Interxion, who will support our Enterprise Computing group, in particular.

Lex is a veteran key international figure in data centres, where he serves as the Chief Data Centre Technology and Engineering Officer for Interxion / Digital Realty, one of the world's largest data centre providers (who provide data centre services to large organisations, including Microsoft, IBM, Uber, etc.). Interxion has major data centres in the UK, particularly in East London. Working with Lex, we will explore opportunities for industrial placements within Interxion data centres and PhD scholarships. Lex holds key positions in organisations such as The Green Grid where he chairs various committees, as well as the European Commission where he serves as advisor on the subject matter. This collaboration will give us the opportunity to work with Lex on some of the major research issues currently being addressed in this field, particularly around Energy Efficiency KPI's, Sustainability and Reliability. This relationship would be valuable for our future research funding bids given Lex's standing. Lex could be very helpful in attracting major industry in any future attempts to create a major UEL data centre hub, not the least being a C level executive in one of the largest data centre organisations globally, with budget responsibility of $500M.

Across the unit, institutional funding was provided to research-active staff to cover research expenses, such as software and hardware equipment, training, and ranked conferences. We invested significantly (over GBP0.5M) in new computer labs: a private OpenStack cloud computing platform, a Digital Security and Forensics Lab, a specific lab for post-docs and PhD students, a recently approved GBP300K multipurpose digital learning hub, and a new Cyber Security and Artificial Intelligence Research and Application Centre which will formally open in 2021.

1.4 Research strategy for the next five years

Building on our achievements since 2014, and reflecting the expansion of our research base, our future strategic aims from 2021 is in line with the institution's 'Future Life' strategic objective. The goals of this objective are for UEL to be in the top quartile of REF2028 impact; to achieve sector-recognition for leading economy 4.0 innovation; while encouraging our economic and societal impact within our East London community. To achieve this, we will work towards improving the key performance indicators of research quality, research impact, innovation growth and international growth, by facilitating impact-led research and knowledge exchange, outreach activities, while

maintaining an emphasis on civic engagement in our department. We propose to achieve this in the following ways:

- Invest in emerging multi-disciplinary and established research areas. We will further invest in staff and infrastructure that will help to position us as a recognised department for delivering innovative solutions to both economic and environmental challenges.
- Manage and deliver impact from our research and communicate this to scientific, business and public audiences. Alongside investment in research areas that can generate impact, we will monitor and facilitate impact, and embed impact delivery into our research training.
- Increase our current collaboration and knowledge exchange with industrial partners on real-world applications of Computer Science and AI. This enables us to produce impactful and real-world-based research, per the institution's long-term strategy for advancing knowledge and innovation.
- Continue the use of internal and external funding to provide a useful budget for all research-active staff.
- Increase the number of PhD scholarships, and set aside funding for PhD students to buy equipment and attend conferences and doctoral summer schools.
- Increase our research focus by utilising the expertise in the department held by our more teaching-focused staff and early career researchers. We propose to establish a fourth research group, namely the Technology Enhanced Learning research group.

1.5 Proposed Research Group

Technology Enhanced Learning (TEL) comprises a variety of innovative technological solutions to deal with numerous evolving educational challenges, including improving the experience of learners, academics, and institutions; providing adaptive, effective, and personalized learning to learners, managing and meeting users' requirements, etc. Overcoming these challenges can empower learners and consequently society and contribute to improving the community quality of life. This interdisciplinary group will focus on the following three key themes:

- Technology for learning and teaching, assessment, and learner experience.
- Best academic practices to support effective formal and informal learning policies.
- Domain-specific education.

Expertise from the current research groups will support this new research area. Technology Advanced Learning artefacts are enabled by various AI technologies and techniques, which can be used to customize the learner's e-learning process, predict their performance, recommend learning activities, etc. Other distributed computing models such as Cloud Computing allow further flexibility so that e-learning scenarios/processes can be enacted/orchestrated using a series of web services. Finally, the substantive rise of adopting Technology Enhanced Learning software systems in real-life scenarios (e.g., academic organisations, lifelong learning, formal/informal learning, etc.) necessitates these software systems to be properly architected using various Enterprise Architecture concepts, standards, and frameworks.

2. People

Our research-active staff are divided into three research groups, see Figure 1. Whilst it is not possible to elaborate in detail all our researchers and their work, we have selected a few individual stories to highlight instead.

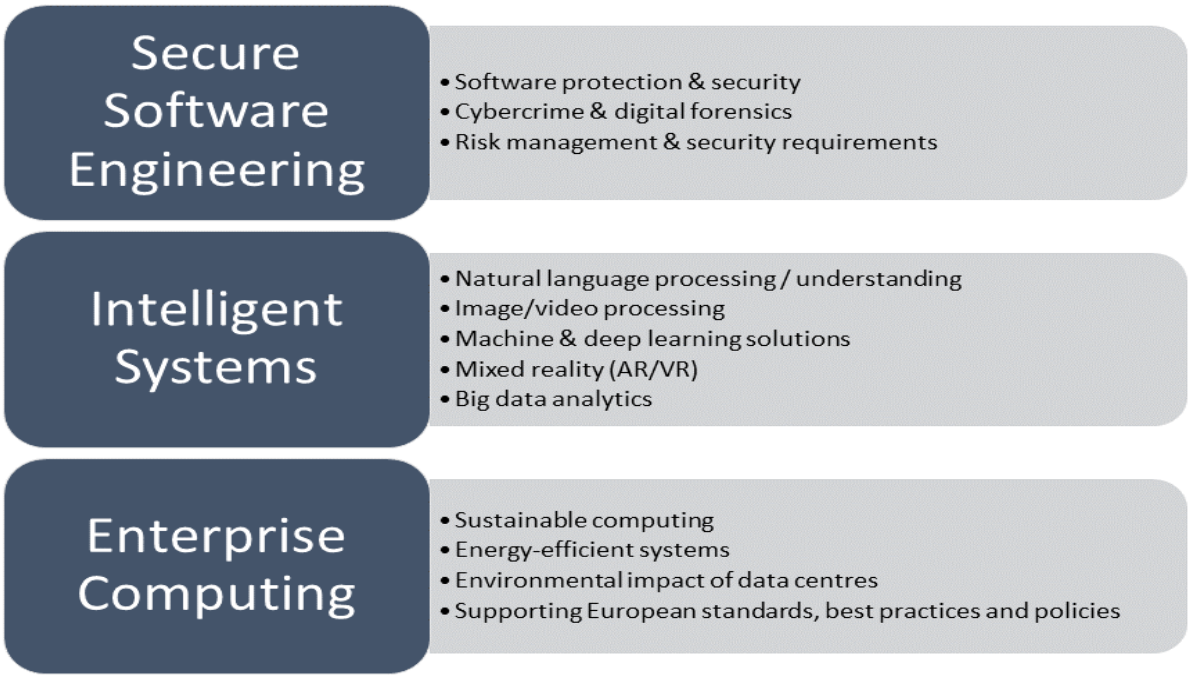

Figure 1 Research groups

2.1 Research Group 1 - Secure Software Engineering

The Secure Software Engineering research group currently has three staff members: Paolo Falcarin (working on software protection and security), Shareeful Islam (risk management and security requirements), and Ameer Al-Nemrat (cybercrime and digital forensics).

Here is an example of a research project from this group:

Dr Paolo Falcarin, Reader in Computer Science, led as principal investigator of the UEL team in the project ASPIRE (Advanced Software Protection: Integration, Research, Exploitation) [5], a 36-month, 3M Euro project funded by the EU FP7 programme (UEL quota GBP390,897), where he worked with six partners across Europe on developing advanced software protections for Android apps against reverse engineering and software piracy.

Flacarin's contribution to the ASPIRE software toolchain [18] is the first software freely offering various code protection techniques against software piracy and copyright infringement, allowing SMEs to improve their software security without paying the exorbitant license fees of the current market leaders. The ASPIRE toolchain has been integrated in commercial products of companies such as Thales and NAGRA-Kudelski.

In particular, the ASPIRE Code Renewability Framework plugin [17] of the ASPIRE Toolchain, led by Paolo Falcarin UEL's team and Ghent University, has helped NAGRA-Kudelski addressing the challenge of dynamically updating crypto-libraries in their digital TV products, deployed across the globe in around 200 million devices, and in 2017 it also helped Thales in improving the security of the first version of the Alicem application, used by the French government to authenticate citizens through their mobile phones.

All the software developed by UEL in ASPIRE has been published open-source and is freely available as part of the ASPIRE toolchain. A YouTube channel [19] was created with thirty demonstration videos of all the ASPIRE protections, industry use-cases and security assessments, reaching more than 10,000 views worldwide.

Figure 2 highlights our collaborative efforts within UEL, with other Universities, with Industry and with Government.

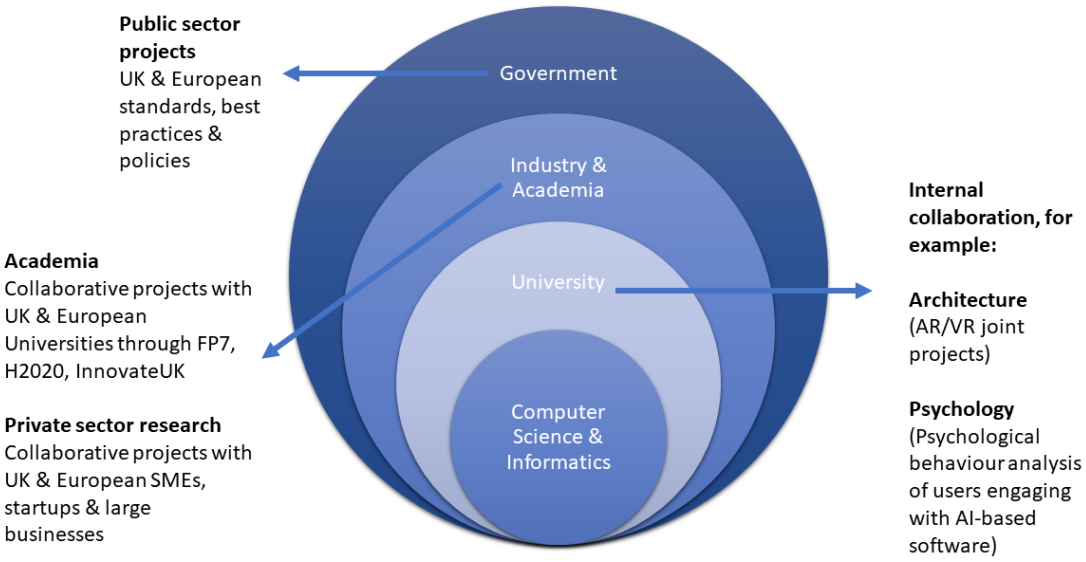

Figure 2 Internal and external collaborative relationships

2.2 Research Group 2 - Enterprise Computing

The Enterprise Computing research group is led by Rabih Bashroush, working on the design and implementation of energy-efficient systems, especially in Cloud and data centre environments.

Here is one example of their world-leading research:

Dr Rabih Bashroush, Reader in Distributed Systems and Software Engineering, is Global Head, IT Infrastructure Advisory at the Uptime Institute, whilst leading this research group at UEL. He plays a key role in driving energy efficiency in the design and operation of data centres and computer servers. Rabih provides strategic advice to public and private sector IT Infrastructure transformation projects covering consolidation, cloud adoption, resiliency and sustainability. He was named in the UK Universities top 100 Best Breakthrough list for his work on energy conservation in ICT and was the recipient of the Industry Initiative of the Year DCD Global Awards 2018. The Breakthrough list demonstrates how UK universities are at the forefront of some of the world's most important discoveries, innovations and social initiatives. It was compiled by Universities UK, the umbrella group for the country's universities, as part of the MadeAtUni campaign to show how lives are transformed through research and practical applications of theory and knowledge.

The work conducted by Rabih in the EU-funded EURECA project [6], which examined the energy efficiency of data centres across Europe, provided the policy team with solid data. It demonstrated that IT servers in Europe remain idle for about 80 per cent of the time, making the introduction of energy caps the right thing to do. His research has impacted various other European policies such as the EU Environmental Management Audit Scheme (EMAS) for Telecommunications and ICT Services sector and the new EU GreenPublic Procurement (GPP) Criteria for Data Centres. Annual savings of over 27 thousand tons of CO2 equivalent emissions can be attributed to research and innovation projects led by him. He has led other European initiatives such as the European Commission DG CONNECT SmartCities research cluster and has advised and supported various governments including the UK, Ireland, and the European Commission.

Other group members are Dr Fahimeh Jafari and two lecturers who recently left (Dr Syed Islam and Dr Joseph Doyle) whose outputs are part of this submission.

2.3 Research Group 3 – Intelligent Systems

The Intelligent Systems Research Centre is led by Professor Mansour Moniri and focuses on applying innovative AI solutions to real-world business problems. Research topics include video, image, audio processing using AI techniques such as natural language understanding, machine and deep learning, big data analytics, mixed reality and recommendation systems.

Here is one example of their research projects:

Dr Julie Wall, Reader in Computer Science, investigates research along the theme of designing intelligent systems for processing and modelling temporal data. She has explored neural network architectures, ranging from biologically inspired modelling to computationally efficient machine and deep learning, to process a variety of data structures from numerical, audio, images, video, to 3D feature data from virtual and augmented reality environments. Julie has a close working R&D relationship with industry, which has involved joint industry-relevant research projects, internationally leading publications and sponsorship for research interns and PhD candidates.

This ongoing successful collaborative R&D history has led to the submission of successful grant applications to Innovate UK, with a combined value of GBP2.2M. One of these projects is one of the four large Innovate UK grants awarded in 2019. This grant funded a post-doctoral research fellow and two research assistants, two of whom are UEL alumni. The work of Julie's team in this project has focused on the development of an explainable AI-based software pipeline that will identify and justify the behavioural elements of a fraudulent claim during a telephone report of an insured loss, using statistical data science approaches and machine/deep learning models. The software developed in this Innovate UK project is being deployed in the insurance sector to tackle insurance fraud. It has also been trialled by the emergency services to tackle hoax calls. In both sectors, the aim is to reduce expensive fraud and unnecessary resource deployment. This work has already been published at Neural Information Processing Systems (NeurIPs), the top-ranked conference in Artificial Intelligence, amongst other top-level conferences. The technology is also patent pending.

Other group members are Dr Saeed Sharif, Dr Amin Karami, Dr Mustansar Ghazanfar, Dr Seyed Ali Ghorashi, Dr Sin Wee Lee, and Dr Fadi Safieddine.

2.4 Staffing strategy

We have invested in high-quality research staff, and our REF submission from 4 FTE in 2014 has tripled to 12.2 FTE in 2021. We have recruited research-active lecturers to join our three research groups, who produce high-quality research in common with our focus of applied research and knowledge transfer. We have invested significantly in the intellectual and creative capital of our research community and value the contributions of all colleagues by:

- providing an environment that stimulates innovation and minimises constraints
- ensuring fairness in the allocation of research support
- recruiting talented, outstanding researchers to bring competence on new technologies
- retaining and rewarding staff who are central to our research strengths.

2.5 Staff Development

We have followed a policy of recruiting, retaining and rewarding high-quality ECRs. For example, Amin Karami and Fahimeh Jafari were hired as lecturers and they are now Senior Lecturers; Julie Wall was hired as a senior lecturer and she is now a Reader and Director of Impact and Innovation for the School of Architecture, Computing and Engineering, Rabih Bashroush, Paolo Falcarin and Ameer Al-Nemrat, who were senior lecturers in REF2014, are now Readers.

We try to provide tailored support to our ECRs. During their first academic year, all ECRs are provided with a reduced administration workload that provides time for developing research ideas and preparing funding proposals. ECRs are identified as PhD supervisors whenever appropriate, joining a supervision team that includes an experienced colleague, ensuring effective staff training and supervision. New staff members since REF2014, Fahimeh Jafari, Amin Karami, Saeed Sharif and Julie Wall, all supervise PhD students, following a well-run mentoring programme supporting their supervision skills base and passing on best practice.

Every ECR and research staff member joins one of the three active research groups, whose leader acts as a mentor providing support for career development, the formulation of publication and networking strategies, and help in preparing research bids. ECRs and research staff are encouraged to gain experience of organising conferences and workshops, supported by their mentor where appropriate. ECRs and research staff are also supported in grant application development by senior staff who provide feedback on proposals before submission. All eligible ECRs have been mentored by senior staff for preparing EPSRC First Grant applications.

Also, the institution's research support team support the impact of projects driven by leading researchers. For example, a post-doctoral researcher was co-funded by the institution to support the world-leading research of Dr Rabih Bashroush. This support has enabled some ECRs to improve their research profile and move to other positions elsewhere: Dr Joseph Doyle moved to Queen Mary, University of London, while Dr Syed Islam moved to JP Morgan. They still collaborate with UEL researchers in writing research bids and co-supervising PhD students.

2.6 Research students

UEL has taken significant steps to improve the experience of our research students as our contribution to developing the next generation of researchers.

In 2015, UEL launched a four-year programme of investment in fully funded PhD scholarships. The publicity generated by this new initiative has resulted in an increase of student applications to the department since 2015. Our knowledge exchange activities have resulted in the initiation of match-funded studentships with industry partners, resulting in challenging research projects that are designed to find bespoke solutions to real-world problems.

All PhD students automatically join one of our three research groups, based on their research topic. However, the supervision team may be made up of staff from different research groups to ensure the required expertise is covered for each project. Like the research carried out by our research staff, our PhD topics focus on developing solutions for economic and environmental challenges. On graduation, our PhD students have been employed by various industries in software development, cybersecurity, digital information, intelligent systems and finance, at leading businesses such as Microsoft, Thomson Reuters, Deloitte, Accenture, Atos, and RBS.

Research supervisors help students develop a full training needs analysis, supported by the Graduate School that manages all applications and recruitment, monitors progress, and organises university-wide training programmes. Formal training is provided through UEL Researcher Development Framework: all new PhD students are required to demonstrate learning from core units on research methods, project planning, research ethics and Intellectual Property laws. Further developmental opportunities for our students arise through participation at UEL’s Annual Research Conference, which provides a collegial, cross-disciplinary and supportive environment in which to gather feedback and responses to ideas in their very early stages.

Computer Science staff have supervised 19 PhD students to completion from 2014 to 2020, and 21 PhD students are going to graduate in the next couple of years.

2.7 Equality and diversity

All appointments adhere to UEL's Equality and Diversity (EDI) Policy. Training on EDI is strongly encouraged for all staff, and additional equalities training is embedded within management training. UEL was awarded an Athena SWAN Bronze Award in 2015, and more recently, the School of Architecture, Computing and Engineering received the Athena SWAN Bronze Award in 2020. UEL holds the Level Two Disability Confidence award recognising our commitment to equality of opportunity for people with disabilities. UEL is also a Stonewall Diversity Champion in recognition of the continuing efforts in creating an inclusive and accepting environment for our LGBT colleagues. In October 2019, UEL established the Office for Institutional Equity, the first of its kind in a UK HEI, to lead UEL's work on equality, diversity, and inclusion (EDI). It was created following an extensive review of UEL's demographics and student outcomes, as well as its existing EDI activities. One of its key aims is to ensure that the gender and Black, Asian and Minority Ethnic mix of UEL senior staff will be representative of the population of London by 2020 (as stated in EDI policy). The OIE administers a mentoring scheme, staff networks and the Many Voices reading group which focuses on giving participants the opportunity to engage with essays and narratives by African diaspora authors, ensuring that both text-based and practice based research is informed by a more diverse knowledge base.

This unit did not submit any female academics for REF2014. The department went through a major reorganisation during the 2013-14 academic year. As a result, 40% of the full-time, existing staff left UEL. Whilst this process was extremely difficult for all concerned, it was necessary to ensure that the Subject Area was 'fit for purpose' and would not just survive but thrive in a highly competitive REF and Teaching Excellence Framework (TEF) focused environment. The re-organisation left a very gender imbalanced area, however, with no female staff remaining. It was important to try and redress this in subsequent recruitment rounds. Since that period 5 female members of staff have been recruited but, unfortunately, 3 of those members of staff have since moved on, leaving two female members of staff in the department. As with every recruitment round, this remains an on-going concern that we are keen to address, and we make efforts to encourage applications from under-represented groups.

UEL's REF2021 Code of Practice includes an EDI section as required and to tackle several of the issues mentioned above, and UEL's Research Excellence Manager has been working closely with the department. Since REF2014, UEL now has an annual research review which includes an equality analysis of research outputs, which helps to identify these issues in preparation for REF.

UEL does not view itself as research-led but as teaching and research-focused, and our research-active staff are also involved in outreach. UEL's borough of Newham and the neighbouring borough of Tower Hamlets have one of the highest levels of poverty amongst older people and children in England. With over 70% of its students from the BAME (Black Asian Minority Ethnic) background, UEL is transforming lives and de-surfacing talents of its local communities and at a global stage. Collaboration is at the heart of our outreach effort and we work with a range of partners across East London, such as schools and colleges, organisations working with young people, young people themselves, their families, local employers and professional/trade bodies, and widening participation organisations and networks to ensure we are delivering fit for purpose outreach. We have a diverse staff for this diverse student body, and our research informs our teaching and outreach, and our collaborative networks are beneficial for our students.

3. Income, infrastructure and facilities

In this section, we describe some of the large-scale, nationally and internationally funded research projects that we worked on. We also describe the micro-level internal funding scheme which has played a vital role in supporting small-scale research activities and internships in our department. We highlight the significant ongoing investments we have achieved in our computing infrastructure and the physical environment.

3.1 Funding Portfolio

During the current REF period, there has been a rapid increase in external grant capture. We have won just over GBP1.97M in external income, mainly from the EU FP7 and H2020 programmes and Innovate UK. Some examples of these concerning our core research themes include:

Example 1 – Secure Software Engineering

Dr Paolo Falcarin worked as principal investigator in the project ASPIRE (Advanced Software Protection: Integration, Research, Exploitation) [2], a 36 month, EUR3M project funded by the EU FP7 programme (UEL quota GBP390,897). Paolo worked with a consortium of three market leaders in security ICT solutions and four academic institutions, from 6 European countries to develop advanced software protections for Android apps against reverse engineering and software piracy, which have been adopted by companies such as Thales and Nagra-Kudelski.

Example 2 – Enterprise Computing

Dr Rabih Bashroush was the principal investigator and coordinator of EURECA [3], a 36 month, EUR1.5M project funded by the EU H2020 programme (GBP308,422 UEL quota), where he worked with partners across Europe on supporting the development of European standards, best practices and policies related to energy efficiency in data centres and green public procurement by providing scientific evidence and data.

Example 3 – Intelligent Systems

Dr Julie Wall is the principal investigator of a 24 month, GBP2M project funded by Innovate UK (UEL quota GBP473,479). This work, in collaboration with the SMEs Intelligent Voice Ltd and Strenuus Ltd, is developing an AI-based explainable pipeline that will identify and justify the behavioural elements of a fraudulent claim during a telephone report of an insured loss.

Example 4 – Knowledge Transfer

To develop more flexible funding streams, Professor Mansour Moniri, Director of Research and Knowledge Exchange helped our unit in funding the following KTP projects with Innovate UK:

- Rabih Bashroush helped Techbuyer Ltd by developing scientific capabilities to model and simulate complex data centre environments (value: GBP194K).
- Shareeful Islam helped Mediprospects Ltd in improving best practices in training by using data analytics (value: GBP160K).
- Julie Wall helped Intelligent Voice Ltd to enhance their video-conferencing services with virtual and augmented reality technology (value: GBP268K).

Micro-Level Internal Funding

All staff have the opportunity to apply for UEL's Funded Internship Scheme, which provides a funded student intern for 3 months, to support pilot studies or contribute to the processing and analysis of research data. The process also provides students with valuable skills and experience of working on real-world Computer Science projects.

3.2 Infrastructure and facilities

UEL has made significant ongoing investments in computing infrastructure and the physical environment since 2014, circa GBP5M.

Computing Labs

The research environment has benefited from significant infrastructure investment including a major refurbishment of the Knowledge Dock Building in 2015, which hosts PhD students and teaching labs. The refurbishment includes the research laboratories, a specialist OpenStack private cloud

computing platform, as well as refurbishment of the cybersecurity labs. The labs include about 88 computers, and 6 switches (also used for teaching). We have 5 racks, hosting our servers and the networking equipment; one of the racks is hosting our OpenStack cloud (10 nodes), which is used by many students and staff for teaching and research.

The school invested in a new lab, the "Chip Forensic Laboratory" managed by Dr Ameer Al-Nemrat, where research is carried out on the latest techniques for decapsulating all types of plastic encapsulated parts in integrated circuits. This lab supports academic study and research, and we often assist law enforcement in data recovery from devices, repairing of damaged chips, and repairing of damaged memory devices.

From 2018 – 2020, another major upgrade took place in all our specialist labs in the Knowledge Dock. A brand-new lab was set up with 60+ machines to support teaching and research activities.

Funding has recently been agreed with UEL to develop additional space in the Knowledge Docks into a state-of-the-art Enterprise Tech Hub, consisting of another 100+ machines and a flexible multi-functional lab set up.

In May 2018, Computer Science students (with the support of staff) launched a student-led "transformation lab. They were given a previously disused Computing lab in the Knowledge Dock to use for this purpose. The IT equipment for this lab was sourced by students from UEL's IT services and refurbished and upcycled by these students. The transformation lab is peer-led and provides a space for senior students to mentor and train their peers in current in-demand industry skills, work on their research projects, and to provide peer-assisted study support sessions.

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

The core ethos of our research is to **develop innovative solutions for economic and environmental challenges**, in line with Goal 9 of the Sustainable Development Goals, while searching for opportunities of **application, commercialisation and knowledge transfer**. Our staff are involved in collaborations internationally and nationally, and our submitted outputs are co-authored with non-UK-based partners from 18 different countries.

4.1 Our research impacts public policy

Members of our staff are involved with world-leading research which impacts public policy. One such example of this is the work of Dr Rabih Bashroush, who has played a key role in driving energy efficiency in the design and operation of data centres and computer servers. His research has impacted various European policies such as the EU Environmental Management Audit Scheme (EMAS) for Telecommunications and ICT Services sector and the new EU Green Public Procurement (GPP) Criteria for Data Centres. Annual savings of over 27 thousand tons of CO2 equivalent emissions can be attributed to research and innovation projects led by Rabih.

Similarly, Dr Ameer Al-Nemrat's research on child exploitation has impacted specifically on digital forensics methods to investigate child exploitation images at the Metropolitan Police. Internationally, advice has been sought by national security agencies, ministry administrators, including the Portuguese National Security Cabinet, the Slovakian National Security Authority during the EU Slovakian Presidency, and the Ministry of Interior in the United Arab Emirates.

4.2 Our research is innovative and collaborative

Our principle of encouraging knowledge exchange has enabled us to enter collaborative research with industry. We have maximised this knowledge spill over into industry using patents. One such example is from Professor Mansour Moniri, who submitted a patent on his Spectral-360 system. This work aimed to address the issue of illumination variation in change detection algorithms. This challenge was addressed using a physics-based approach to model the spectral reflectance of surfaces. This novel technique (called Spectral-360) was patented [15] and rated amongst the top four best algorithms by IEEE Change Detection Workshop 2014.

This research work was also substantiated through applications undertaken for London Underground, Staffordshire Police, Leicestershire Police and Defence Science and Technology Laboratory (DSTL). For example, Spectral-360 enabled Staffordshire police to efficiently & accurately prepare evidence to go to the court, this involved CCTV and video footages with severe changes in illumination conditions.

Shareeful Islam has been funded by the Innovate UK academic start up accelerator programme to develop a Cyber Insurability toolkit that can manage cyber-risk by assisting with decisions on suitable control strategies to mitigate cybersecurity risks.

Our staff have active research collaborations with international universities and industries:

- The Secure Software Engineering research group is collaborating with Ghent University (Belgium), Aalto University (Finland), Politecnico di Torino (Italy), Technical University Munich (Germany), NAGRA-Kudelski, and Thales.
- The Enterprise Computing research group is collaborating with Green IT Amsterdam, University of Leeds, Data Centre Trade Association, Carbon3IT, CBRE, Centre for Environmental Policy at Imperial College, KTH Stockholm (Sweden), and TU Wien (Austria).
- The Intelligent Systems research group is actively working with University of Southampton, University of Taxila (Pakistan), Queen Mary University of London, Intelligent Voice Ltd, King's College London, NHS Manchester Royal Eye Hospital, University College London (UK), and Brunel University London.

4.3 Our research has international media reach

Many of our staff are highly active in engaging with the media. One such example is Dr Ameer Al-Nemrat who has frequent media appearances [21] and published articles on Sky News , BBC, Al-Jazeera [14], BBC Radio 4, The Times [13], providing commentary and opinions on the problems of cybercrime and digital forensics.

Another example involves Dr Rabih Bashroush who was invited by Dispatches (Channel 4's award-winning investigative current affairs TV programme) in 2020, as an expert on ICT sustainability for the episode "Is Your Online Habit Killing the Planet?" [4].

Similarly, Dr Sin Wee Lee has been invited to be the subject expert on data analytics and the dark web on numerous occasions. He has been interviewed for his work across multiple media outlets, including a front-page article in The Times [7], and further articles on BBC morning news programmes, The Guardian [8], New Statesman [9], Daily Mail [10], International Business Times [11], and the Express [12].

4.4 Our publications, invited talks and awards

We **publish the outputs of our research in top-rated conferences** (*Conference and Workshop on Neural Information Processing (NeurIPS), IEEE International Joint Conference on Neural Networks, Interspeech*) **and journals** including *IEEE Transactions on Cybernetics*, *IEEE Internet of Things Journal*, *Elsevier Future Generation Computing Systems*, *Elsevier Expert Systems with Applications*, *Elsevier Information Sciences*, *Elsevier Journal of Systems and Software, ACM Transactions on Privacy and Security, IEEE Transactions on Cloud Computing, and Springer's Empirical Software Engineering*.

Our staff are regularly **invited to deliver talks and participate as panel members at research conferences and major industrial forums**. Some examples of these include:

- Dr Paolo Falcarin was an invited speaker at the OWASP (Open Web Application Security Project) conference (2017), the Infosecurity conference (2018), and the IET Conference on Cyber Security and Systems Safety (2018). He was invited to attend a High-Level Workshop on the Network of Cybersecurity Competence Centres (2018), a wide consultation among cybersecurity experts in Europe on the creation of a European Research and Competence Centre and the definition of the cybersecurity topics for the post-H2020 EU research programme.

- Dr Rabih Bashroush was invited as the keynote speaker to the International Workshop on Energy Efficient Data Centres (2017), to the Data Centres North industrial event (2016). He served as an expert panel member at the industrial expo Data Centres Ireland (2017), in Dublin. Rabih also chaired an expert panel session at the Data Centre World (DCW) London (2017) and he was invited to deliver a webinar on Tools and Services for Energy Management by the ICT footprint.eu European Commission platform in 2016.

- Dr Julie Wall has participated in many roundtable discussions on the topic of explainable AI. She moderated a round-table discussion on 'Disruptive Technologies – the opportunities and challenges' (2018), which included the MP Stephen Metcalfe and several CEOs/CTOs from London-based technology companies. Julie was invited as speaker and expert panel member to the RE.WORK AI Applications Virtual Summit 2020.

- Dr Saeed Sharif was invited to deliver an IET public talk in 2015, after which he was invited to deliver a talk on his research at the Wroclaw University of Technology in 2015. In 2020, Saeed was invited as the keynote speaker at the International Conference on Intelligent Control and Computation for Smart Energy and Mechatronic Systems.

Our **research has attracted awards**, some examples of these include:

- The EURECA Consortium, led by Dr Rabih Bashroush, won an Industry Initiative of the Year award at the DCD Awards in London 2018. The DCD judges were impressed with EURECA impact on improving energy efficiency across Europe, saving data centres at least 52GWh per year.

- Dr Paolo Falcarin and Dr Shareeful Islam received the best paper award at the IEEE Cybersecurity Conference 2016. Paolo also received the Best Paper Award and ACM Distinguished Paper Award at IEEE International Conference on Program Comprehension (ICPC) 2017.

4.5 Our researchers contribute to the research community

To maintain and enhance our status in the community, staff are encouraged to undertake leadership roles within the academic community.

Major leadership roles include chairing workshops and panels, being **members of high ranking conference committees and journal editorial boards**, examples include *IEEE Transactions on Information Forensics and Security*; *IEEE Transactions on Cloud Computing*; *IEEE Access*; *Springer Neural Computing and Applications*; *IEEE Transactions on Cybernetics*; *Elsevier Neurocomputing*; *Elsevier Journal of Network and Computer Applications*; *Elsevier Engineering Applications of Artificial Intelligence*; IEEE International Joint Conference on Neural Networks*; IEEE Internet of Things Journal*; *Elsevier Signal Processing*; *IEEE Transactions on Signal Processing*; INTERSPEECH; and *IEEE Transactions on Wireless Communications*.

Our researchers have served as **reviewers for project proposals** for research councils, such as the EPSRC and the Leverhulme Trust.

We are **members of professional organisations and learned societies** relating to our research areas, such as IEEE; IEEE Computational Intelligence; IEEE Women in Engineering; Cambridge Wireless; British Computer Society; and the IET.

Dr Falcarin created the International workshop on Software Protection (SPRO) [20], co-chairing two editions with industry leaders; SPRO was co-located with ICSE-2015 and CCS-2019 top conferences, and it reached more than 80 participants from academia and industry in each edition, and it has been merged into the new Software Attacks and Defences (SAD) Workshop since 2020.

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