UNIVERSITY OF CAMBRIDGE
Department of Computer Science and Technology

Annual Report of the Faculty 2019-20*

*A small number of items that fall into 2020-21 which are of current relevant interest are also included in this report

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INTRODUCTION

The Department of Computer Science and Technology is a world-class research facility combining theory with practical activities, and significantly advancing both the field and computing in the wider world. We sustain active research across the breadth of computer science – and continue to do so despite the challenges of the Covid-19 pandemic – and we encourage the development of new technologies and applications. We are also highly sought-after for our teaching. Despite the pandemic, our undergraduate numbers are only fractionally down at the start of 2020-21, while the number of PhD admissions has risen significantly.

2019/20 was the Department's second full academic year under the headship of Prof Ann Copestake. It was inevitably a challenging one, but though the challenges remain we are heartened by the strength of research and teaching here. However, as outlined later in this report, space issues will significantly constrain our work in future unless properly addressed.

The University's Strategic Research Review of the Department in September 2018 was a valuable opportunity for us to reflect on and strengthen the ways the Department's strategy is enabled in practice. In the appendix, you will find our thoughts on the recommendations of the review panel and greater detail of how we continue to respond to them.

We made a number of new academic appointments in 2019/20 which, in particular, has strengthened our contribution to the important field of Machine Learning/Artificial Intelligence – a key area where computer science has the potential for huge social impact and where we wish to lead. We have also continued to improve our support for early career researchers in this field by the creation of Departmental Early Career Academic Fellowships (DECAFs) in Machine Learning or Data Science, to which we have currently appointed four members of staff.

STAFF OVERVIEW

As of 30 September 2020, the Department of Computer Science and Technology consisted of 202 members of staff:

Academic staff	53
Academic-related & Assistant staff	38
Research Fellows	6
Research Staff	105

New Staff

Professor Srinivasan Keshav joined the Department on 1 October 2019 as the Robert Sansom Professor of Computer Science. Before coming to Cambridge Keshav was at the University of Waterloo, holding first a Canada Research Chair and then the Cisco Chair in Smart Grid. Keshav's research interests started in computer networking but since 2010 his focus has been on reducing the carbon footprint of energy generation, transportation, and buildings. He has also recently turned his attention to the carbon sequestration and biodiversity potential of forests, looking at both conservation and restoration.

Professor Neil Lawrence joined the Department on 1 October 2019 as the DeepMind Professor of Machine Learning. Prior to this, he was the Director of Machine Learning at Amazon Cambridge. Neil also retains a visiting position at the University of Sheffield as Professor of Machine Learning. His research interests are

in probabilistic models with applications in computational biology, personalised health and developing economies.

Dr Cengiz Öztireli joined the Department as a University Senior Lecturer on 1 October 2019. Cengiz was previously a Research Scientist at Disney Research, Zurich and a Lecturer at ETH. Cengiz's research specialises in computer graphics, vision, and machine learning/artificial intelligence, with the aim of realising a form of digital reality that is easy to create, manipulate, and experience.

Dr Jeremy Yallop joined the Department as a University Senior Lecturer on 1 April 2020. Jeremy was previously a Senior Research Associate in the Department. His research focuses on the design and use of functional programming languages and on user-defined optimization.

Dr Jamie Vicary joined the Department as a University Senior Lecturer on 1 April 2020. He also holds a Royal Society Research Fellowship. Jamie was previously a Senior Lecturer in the Theoretical Computer Science Research Group, University of Birmingham. He works on higher category theory and its applications in computer science and mathematics, particularly in areas related to quantum structures.

Dr Nicholas Lane, joined the department in May 2020. He was formerly an Associate Professor in the Computer Science Department, University of Oxford. Nic's research is in the design, architecture and algorithms of scalable and robust end-to-end machine learning systems. His interests drive towards the development of new forms of ML systems that are revolutionary in how they leverage multi-modal data to infer and reason over complex real-world situations — while simultaneously, maintaining extreme levels of systems flexibility.

Dr Carl Henrik Ek, joined the Department as a University Senior Lecturer on 1 June 2020. He was formerly Senior Lecturer in the Faculty of Engineering at the University of Bristol. Carl Henrik's research interest is in how we can specify data efficient and interpretable assumptions that allows us to learn from small amounts of data. Most of his work is focused on Bayesian non-parametric methods and in specific Gaussian processes.

Dr Ferenc Huszár, joined the Department as a University Senior Lecturer in July 2020. He was formerly a Senior Machine Learning Researcher at Twitter. Ferenc has broad interests in many areas of machine learning, in particular principled deep learning techniques: optimization, generalization, representation, transfer and meta-learning.

Dr Weiwei Sun, joined the Department as a University Senior Lecturer on 1 September 2020. Prior to joining Cambridge, she was an Associate Professor at Wangxuan Institute of Computer Technology of Peking University. Weiwei is a Computational Linguist and her interdisciplinary research leverages computational models to investigate fundamental linguistic questions and developing linguistically-motivated technologies to advance Natural Language Processing applications

Professional Services Staff

Helen Francis, Research Strategy Manager
Rachel Gardner, Digital Communications Coordinator
Graham Hatt, IT Support Manager
Ben Karniely, Research Strategy Administrator
Andrea Lorenz, Coordinator, Trust and Technology Initiative
Quo Pham, HR Manager (on secondment from HR Division)

Jessica Montgomery, Programme Manager/Executive Director, Accelerate Programme for Scientific Discovery

Personal Promotions

The following members of staff enjoyed personal promotions from 1 October 2020.

Professorships:

- Tim Griffin
- Richard Mortier
- Andrew Rice

Readers:

- Thomas Sauerwald
- Robert Watson

The following Research Associates were promoted to Senior Research Associate:

- Dr Ali Ozgur Yontem, Graphics and Displays Group
- Zohreh Shams, Artificial Intelligence Group
- Jonathan Woodruff, Computer Architecture Group

Leavers

We were sorry to lose six key members of staff during 2019-20:

- Jonathan Goddard, Digital Communications Officer
- Dr Martyn Johnson, Senior Computer Officer
- Brian Jones, Computer Associate
- Tara Leggett, Undergraduate Student Administrator
- Dr Graham Titmus, Senior Computer Officer
- Professor Glynn Winskel, Professor of Computer Science

We wish them all well in their future endeavours.

College Fellowships

The Department continues to strengthen its links with the Colleges and following staff have taken up a College Fellowship:

- Prof Neil Lawrence, Queens' College
- Dr Jamie Vicary, King's College
- Dr Jeremy Yallop, Robinson College
- Professor Srinivasan Keshav, Fitzwilliam College

Honours, Awards and Achievements

We are pleased to report numerous staff and student honours, awards and achievements over 2019-20 (https://www.cst.cam.ac.uk/news). A selection of these include:

Success at Northwestern Europe Regional Contest (NWERC): In November, three teams of Cambridge students enjoyed success at the NWERC, an annual programming contest, in Eindhoven. The Cambridge teams were amongst the most successful at the contest, coming in second, seventh and eighth place among 123 teams. The annual competitive programming contest sees teams of up to three university students aim to design algorithms to solve programming problems.

ERC Consolidator Grant Award: In December, Dr Andreas Vlachos was awarded an ERC Consolidator Grant for the project "Automated Verification of Textual Claims" (AVeriTeC).

Distinguished Paper Award: In January, Dr Neel Krishnaswami, together with Michael Arntzenius (of the University of Birmingham), received a Distinguished Paper Award for their research paper at POPL (Principles of Programming Languages) 2020.

Award for work conducted more than 20 years ago: In May, Dr Markus Kuhn, University Senior Lecturer in the Department, was presented with an award for work that he and colleagues conducted more than 20 years ago. Markus and his co-authors were honoured with the 'Test of Time Award' for their paper 'Analysis of a denial of service attack on TCP' at the 2020 IEEE (Institute of Electrical and Electronics Engineers) Symposium on Security and Privacy. The award recognizes past papers for their broad and lasting impact on both research and practice in computer security and privacy.

PhD student named as an Apple Scholar: In July, PhD student Yiren 'Aaron' Zhao was named as an Apple Scholar in a programme created by Apple to recognise emerging leaders among computer science and engineering postgraduates. Aaron is one of a cohort of 12 outstanding PhD students who will receive a two-year Apple Fellowship in AI/machine learning. He is a PhD student in this department working under the supervision of Dr Robert Mullins. His research focuses on efficient machine learning, secure machine learning and machine learning hardware designs.

''A First Step Towards On-Device Monitoring of Body Sounds in the Wild' wins student Best Paper award: A paper based on work by Shyam Tailor was submitted to this year's International Workshop on Computing for Wellbeing, where it was selected as the Best Paper. The paper was co-authored with Shyam's Master's supervisor, Professor Cecilia Mascolo, co-director of the Centre for Mobile, Wearable Systems and Augmented Intelligence and postdoc Jagmohan Chauhan. Shyam is a PhD student who has just returned to Cambridge from the University of Oxford to continue pursuing his PhD here in Dr Nic Lane's group.

Distinguished Paper award from the International Conference on Functional Programming 2020: In September, a group of systems researchers here in the Department, along with their industrial and academic collaborators, celebrated receiving a prestigious award for a breakthrough that took them six years to achieve. The OCaml Labs team collected a Distinguished Paper award from the International Conference on Functional Programming 2020 for their paper Retrofitting Parallelism onto OCaml. The award honours their work in solving a hugely challenging issue: adding parallelism to a widely used functional programming language with millions of lines of existing code, while also maintaining backwards compatibility.

SIGMOBILE's 'Rockstar' early career award: Earlier this year, Nic Lane was named as the recipient of SIGMOBILE's 'Rockstar' early career award 2020 for his outstanding contributions to mobile computing. SIGMOBILE - the ACM Special Interest Group on Mobility of Systems Users, Data and computing - awards this honour annually to an individual who has made recent outstanding research or product contributions to the field of mobile computing during the early part of their career.

The **Wiseman Prize** aims to recognise students and research staff who make an exceptional contribution to the work of the Department which is beyond their expected 'duties'. Their outstanding contributions make a real difference to our work. The recipients for their contributions during 2019-20 were:

- Mahwish Arif
- Apinan Hasthanasombat
- Jack Hughes
- Tobias Kohn
- Qingbiao Li
- Shaun Steenkamp
- James Thorne

ACTIVITIES

Supporters Club

The Supporters' Club is a group of companies who value interaction with our students, mostly for the purposes of recruitment, and pay a modest annual subscription in exchange. Members can, amongst other benefits, give Tech Talks, engage in Part IB projects, advertise opportunities and events to students, attend an annual dinner, and take part in the Recruitment Fair. Members cover the whole spectrum from start-ups to multinational enterprises; an explicit goal is to provide our students with a wide diversity of opportunities.

The Club has grown over the last five years to around 90 members; expansion beyond that has been constrained chiefly by the space available for the Recruitment Fair, which takes place over two days in the Michaelmas term, with around 40 companies typically attending on each day.

Subscriptions have traditionally been by pure donation, at an amount discussed informally with the company concerned, but averaging around £1000 per member per year. The funds raised are, where possible, used for 'noble' causes within the department, such as outreach activities, alleviating student hardship, support of groups such as women@CL, and providing funding for early-stage research.

It was becoming apparent this year, however, that subscriptions could no longer be considered pure 'donations', since members were receiving rather tangible benefits in return (some of which were also VAT-able). After prolonged discussion, the subscription was split into three parts: a basic membership, a fee for the Recruitment Fair, and a donation component for those able to contribute further. Though perhaps unavoidable, this has made the bureaucracy more complex and has slightly reduced the income per member, since it makes more apparent the minimum contribution needed to participate! Investigations of ways to mitigate both of these are ongoing.

The budgetary uncertainty of this year for many organisations, often combined with a reduced emphasis on recruitment, has led to a reduction in membership, though this has been much less substantial than initially feared. At the time of writing, membership stands at 85 companies, down from the mid-90s at the same time last year.

The highlight of the Club's year has historically been the vibrant and energetic mêlée that is the Recruitment Fair. Its traditional form, however, is not in any way compatible with the phrase 'social distancing', so this year an online version was held at the end of October using software developed in-house (loosely based on a speed-dating model!) Forty members took part, uploading brief video

introductions and other information about their companies, and the system offered a variety of options for interaction with attendees. It attracted over 260 visitors, who initiated 375 live chat sessions and 444 'email introduction' messages.

Most other activities, such as the Tech Talks, have been proceeding as normal this year but in virtual form, and it will be interesting to see the effect this has upon student attendance numbers.

Cambridge Computer Lab Ring

The Ring is the Lab's alumni association. Originally restricted to graduates of the Department, we have now extended the membership criteria to include past staff members and longer-term visitors, and also graduates of other departments who were significantly involved with Computer Science whilst in Cambridge.

In the past, though, only a small fraction of those eligible to join, even within our own department, had actually signed up as members. The reasons were varied: in some cases they graduated long before the Ring even existed, others only heard of it in the early days when subscription payments were required, some slipped through the gaps and weren't notified when they graduated, and all of these were difficult to correct because the department typically does not have good contact details for students once they leave.

In 2019, the Cambridge Ring was brought under the management of the Department's Research Strategy Team, which put more membership management structure in place and undertook a significant recruitment and data-gathering effort in conjunction with the University's alumni relations department. We have also increased the frequency of communication with alumni and surveyed them to learn more about how they wish to engage with us and each other. Membership has subsequently doubled, and we are looking forward to an increase in engagement with our alumni.

The 'Hall of Fame'

The Ring's annual 'Hall of Fame' awards are given in four categories: the company of the year and the product of the year (from among the almost 300 companies started by staff and/or graduates of the Department); the publication of the year (from among those produced by members of the Department); and the Better Future Award – which is intended to recognise those who have made significant contributions to humanity through technology. The awards are normally presented at the annual Ring dinner, but this was postponed twice before eventually being cancelled, as a result of Covid restrictions. An alternative video-based award presentation has therefore been recorded, and the winners will be officially announced at about the same time as this report!

Wheeler Lecture

The annual Wheeler Lectures are held in memory of Professor David Wheeler, one of the pioneers of Computer Science. This year it was given by alumna Dr Sophie Wilson, who looked at the history of microprocessors, how we got to where we are now, and what constraints there are on the future. This lecture is usually delivered in person but this year it went online – which was perhaps just as well, as it proved extremely popular and we could not physically have fitted the 350 attendees into Lecture Theatre 1.

Sophie co-designed, with her colleague Steve Furber, the BBC Microcomputer, BBC BASIC and the Acorn Assembler. They then went on to design the ARM processor, which originally powered Acorn's computers, and is now the core of virtually every mobile phone and tablet in the world – 75 billion ARM-powered chips

have been sold to date.

Sophie is a Broadcom Fellow and Distinguished Engineer, a Fellow of the Royal Society, a Fellow of the Royal Academy of Engineering, a Fellow of the British Computer Society, a Fellow of the Women's Engineering Society and an honorary Fellow of Selwyn College, Cambridge. She has an honorary doctorate of science from Cambridge University and a CBE

RESEARCH

The Department continues to produce world-leading research and this activity is at the heart of the Department's activities. https://www.cst.cam.ac.uk/research. Research grant income in the last financial year was £10,230,981m.

A selection of Research Grants received between October 2019 and September 2020 include:

- **Professor Cecilia Mascolo** ERC, Audio-Based Mobile Health Diagnostics – EAR
- **Professor Andrew Rice** Intel Corporation, Integrating Machine Learning into the Die
- **Professor Richard Mortier** Innovate, West Cambridge Digital Twin Research Facility
- **Dr Andreas Vlachos** Facebook Inc, Textual Claim Verification via Knowledge Graph Construction
- **Professor Pietro Lio** EC H2020, GO-DS21: Gene Overdosage and comorbidities During the Early Lifetime of Down Syndrome
- **Professor Alastair Beresford** Department for Education, Isaac Physics
- **Professor Jon Crowcroft** ESRC, Legal Systems and Artificial Intelligence
- **Dr Alice Hutchings** EPSRC, CYBERCRIME NLP: A Natural Processing Toolkit for the Interdisciplinary Analysis of Underground online Forums
- **Dr Mateja Jamnik** EPSRC, Automating Representation Choice for AI Tools
- **Professor Peter Sewell** TSB/Innovate, Digital Security by Design (DSbD)
- **Professor Alan Blackwell** Microsoft Research Ltd, Prototyping a Decision Support Tool in Postoperative Cardiac Surgical Patients
- **Dr Emily Shuckburgh** TSB/Innovate, Standard for Environment, Risk and Insurance: SERI
- **Professor Ross Anderson** EPSRC, Covid-19 Tracking Covid Cybercrime and Abuse
- **Professor Simon Moore** EPSRC, SIP – Secure IoT Processor Platform with Remote Attestation

In September 2018 the University undertook a Strategic Research Review (SRR) of the Department. The Head of Department's recent summary of progress since that review, including responses to the specific recommendations of the review panel, is included as an Appendix to this report.

DONATIONS

Donations received between October 2019 and September 2020 include:

The Accelerate Programme for Scientific Discovery

The Accelerate Programme is supported by a generous donation to the University from Schmidt Futures, a philanthropic initiative founded by Eric and Wendy Schmidt. Led by Professor Neil Lawrence, DeepMind Professor of Machine Learning, the programme is initially aimed at researchers in STEMM (science,

technology, engineering, mathematics and medicine), but will grow to include arts, humanities and social science researchers who want to use machine learning skills to accelerate their research. The first Schmidt Data for Science Residency Programme, which ran for five weeks from 20 July 2019, was offered to PhDs and postdocs in science disciplines across Cambridge, and attracted 27 PhDs and postdocs.

arm donation to women@CL

In September 2020, arm made an unrestricted gift to the department to support the women@CL network. women@CL intends to use some of these funds to offer financial support to its members for training, attending conferences and outreach activities.

Deep Mind

DeepMind supported a further five scholarships This gift builds on the success of the first cohort of DeepMind Cambridge scholars and will fund up to three one-year Master's courses and two three-year PhD scholarships in the fields of Computer Science and Machine Learning. These scholarships aim to attract talented postgraduates from the UK and EU who identify as female and/or are of Black or minority ethnic backgrounds - groups who are under-represented in the study of Computer Science. The DeepMind scholarships can change the lives of students who would not be able to take up the offer of admission without financial assistance.

TEACHING

Undergraduate Teaching

As expected, the effect of the coronavirus virus outbreak has impacted on the Computer Science Tripos admissions and examination results in 2020. A total of 114 Part IA students were admitted in Michaelmas Term 2020. That is slightly fewer than the planned 120 but is not a significant drop in numbers. These break down into 88 home students, 25 of whom are EU students, and 26 international students. The percentage of female students has risen to 24%, returning to comparable levels pre-2019.

The coronavirus impact on the Tripos exams was much more significant. The examinations were all held online using Moodle and were 'open book'. Only Part II students were classed this year. Part IA and IB answered the papers and were given a mark for each question which their Directors of Studies were able to use to give formative feedback and to check on progress.

The Department offered a second sitting of Part II exams in September for those students taken unwell or struggling in any other way. There were 101 students on the candidate list. One withdrew, one was an NFH (not for honours) student, 93 were classed in June and 6 in September.

The initial boundaries were set at the percentages shown in the box below. To mitigate against the considerable difficulties that students faced, a safety net was applied to raise any class which was below that achieved by the student in Part IB. The final results awarded are also shown in the box below.

2020 Results

Initial boundaries		Final results	
I	40%	I	51%
II.1	48%	II.1	46%
II.2	9%	II.2	2%
III	3%	III	1%

2020 and 2019 Results

2020 Part II results		2019 Part II results	
I	51%	I	40%
II.1	46%	II.1	49%
II.2	2%	II.2	9%
III	1%	III	2%

All students received their results in time to progress to their chosen courses for 2020 – 21 where this was dependent on their result.

Postgraduate Teaching

The MPhil in Advanced Computer Science continued to run smoothly throughout 2019/20 and the timing of the lockdown meant that the coronavirus had less impact on the course than the CST Tripos, as the vast majority of teaching and assessment had been completed prior to lockdown. After lockdown, the supervision of the projects and the examination process moved online without any difficulties. We were very pleased to receive the External Examiner's positive comment that he was extremely impressed with the diligent and professional way the examination process had been conducted.

Application numbers for the MPhil have remained very strong and 62 students started the course in October 2020. We also have a record number of PhD admissions (51) in 2020-21.

OUTREACH

The Department participated in the University Open Days in July 2020 (which this year were run virtually). We offered visitors a pre-recorded talk giving an overview of the Tripos and the application process for Computer Science. There was also a sample lecture to view and a video from one of our undergraduates who interviewed some of his peers to explore studying Computer Science at Cambridge. The Department maintained a live FAQ web page, with a dedicated email address for visitors to email in their queries and obtain a personal response.

In a similar vein, the Sutton Trust Summer School also moved online, running from 17-21 August with 41 students attending. Students were given a programme of pre-recorded lectures on specific topics, Python coding challenges, magazine articles on topical Computer Science issues, supervision-like problem solving and taster lectures from other areas in the subject. Dr Tim Jones, who organises the annual Summer School here, reported that despite not being able to run it in person, "we're still able to get to know the students and interact with them via our daily Zoom meetings and online discussion forum." And our participants enjoyed it. Troy, a student from Eastleigh, Southampton said: "I'm really enjoying the summer school so far and it's been good to get a deeper insight into what Computer Science is like at university! I feel like I've already learnt a lot."

The Postgraduate Education Office participated in the Postgraduate Studies Open Day on 1 November 2019. The Department offered course talks from the Deputy Head of Department, Professor Cecilia Mascolo; talks from current research students including segments about their journeys to their PhDs; poster presentations; and information desks at both the University Centre and the department.

Earlier in the year the Department managed to run an in-person outreach session with a group of 50 Year 10 pupils from nearby schools as part of a wider university-led Science and Technology day.

Professor Ann Copestake
Head of Department, November 2020

APPENDIX: SUMMARY OF PROGRESS SINCE THE STRATEGIC RESEARCH REVIEW (SRR)

Introduction

When the General Board originally considered the SRR, the Pro-Vice-Chancellor, Research, commented that:

> **the Department should play a key role in informing all areas of the University about Artificial Intelligence in particular, an area of increasing importance**

It therefore seems appropriate to start by discussing Machine learning/Artificial Intelligence. At the time of the SRR, this was the area of our greatest weakness (relative to other top-ranking CS departments: although machine learning (ML) was well-established in all our research groups, we had too few specialists in the subject given its huge importance and student demand. We have made considerable progress in addressing this over the last two years. We recruited Professor Neil Lawrence from Amazon as the first DeepMind Professor of Machine Learning in 2019 and three additional specialists in ML have subsequently joined as USLs (Dr Carl Henrik Ek, previously at Bristol; Dr Ferenc Huszar, Twitter; Dr Nicholas Lane, Oxford). The standard of applications was extremely high for these posts: we had over 120 applicants, despite the extraordinary demand from industry for specialists in this area. Three other positions went to researchers who combine ML with another specialism: Dr Cengiz Oztireli (Disney Research/ETH) has expertise in graphics and ML, Dr Weiwei Sun (Peking) works on Computational Linguistics and ML, and we recruited Dr Emily Shuckburgh to a new Readership in Environmental Data Science. We are very involved in the new CDT in AI for Environment Risk (AI4ER) which Dr Shuckburgh leads: of the 10 students starting their PhDs, six have main supervisors from CST, and two others are co-supervised.

We obtained a substantial donation from the Schmidt Foundation for the 5-year Accelerate programme to enhance the use of AI in scientific research across the University. This will allow the recruitment of a number of staff and research students, including four departmental fellows whose research spans machine learning and scientific disciplines and two research software engineers to support interdisciplinary ML research and teaching. As with the DeepMind endowment, this success was based on stellar work by CUDAR.

We made three other appointments of academic staff since the SRR. Professor Srinivasan Keshav moved from the University of Waterloo to take the Robert Sansom chair, replacing Professor Ian Leslie. His interests in renewables and climate change fit very well with the CDT in AI4ER and he is now a Deputy Director. We have also appointed Dr Jeremy Yallop (SRA, Cambridge) and Dr Jamie Vicary (Birmingham/Oxford, Royal Society University Research Fellow) to Senior Lectureships to work in theoretical Computer Science.

We have had considerable success in recent funding. We have eight current ERC grants in the Department, of which five were obtained since the SRR. Two UKRI fellowships and a major Turing fellowship have also been obtained in the last two years. Several of our major longer-term projects have had notable successes: the CHERI project played a leading role in the creation of the £70m UKRI Digital Security by Design (DSbD) programme, while IsaacComputerScience.org was launched with funding from the Department of Education. Combining the expertise in Isaac together with ALTA, we have the potential to be a world-leader in research in machine-enhanced teaching and learning, in partnership with Cambridge Assessment and CUP.

The average number of incoming PhD students averaged around 25 from 2014 to 2018, but increased to

40 in 2019-20 and to over 50 this year. This is discussed below as there were specific recommendations from the SRR concerning PhD studentships.

The gender balance in the Department is steadily improving, though from a very low base. In 2014 there were only 4 female UTOs, but we now have 11 – one more than at the time of the SRR. Of the UTOs in the Department, 21% are women (two UL, two USL, two Readers and five Professors). The proportion is roughly the same at all levels of seniority, so at least we avoid the usual drop-off. Because of the Athena SWAN process, we have tended to focus on gender, but in future we need to consider other aspects of diversity more closely.

Most of our research has been able to continue during the Covid-19 crisis, though with some difficulties. Several lines of research were (re)directed towards Covid-19, including studying cybercrime during lockdown, machine learning for intensive care patient stay prediction and audio-based diagnostics for Covid-19 sounds. Professor Crowcroft and Dr Yoneki's pioneering (2011) work on digital contact tracing has been widely reported. Professor Lawrence is a member of the Royal Society's Covid-19 data analytics effort, DELVE.

Increasing the number of professional Services staff supporting research has been a major undertaking. This is discussed below, since it relates directly to the SRR recommendations, to which we turn.

Finance

Recommendation 1. The University is encouraged to review the revenue distribution system in place to better reward successful efforts by the Department that generate financial reward for the University, such as additional teaching programmes, success in overhead-bearing research funding and commercially successful spinoffs.

Comment by the General Board: The Head of the Research Office indicated that the Department could usefully develop more philanthropic opportunities by building relationships with successful alumni. Such fundraising would be vital for the growth of the Department and further facilitate the Department's competitiveness in the international field.

Financial matters were a major focus of the review. Although the recommendation above is addressed to the University rather than the Department, we think it important to mention here, because the Department is very keen to do whatever it can in conjunction with the University to improve the situation. These are not new issues, of course, but we want to emphasise that progress towards solving them is a prerequisite for our development of a sustainable strategy for large-scale industrial collaboration. It is also a prerequisite for engagement with some of our most wealthy potential donors, who are well aware of the issues.

We hope to play an active part in addressing this. We initiated the School of Technology's 'AI Strategy', which proposes increasing the number of Masters' students in CST and Information Engineering (especially in Machine Learning), while retaining some of the fees at Departmental level. Covid-19 has somewhat delayed implementation of this, but we have a record intake of students at Masters' level, so have confidence that the approach is still feasible from that perspective. The full AI strategy requires further philanthropic funding for fellowships and attempts to raise this are ongoing. Much better understanding of research costs is also needed and we are hoping to actively cooperate with efforts at central level to develop better financial models using the Department as a test case.

Communications

Recommendation 6. The Department is advised to establish a PR/communications position to better

represent and communicate the quality and scope of research profiles and activities across the Department

We described some initial actions in our original response to the review. The Digital Communications Coordinator is now part of the new Research Strategy Team (described below). We are very happy with the progress and believe we are becoming much better in communicating our success stories at all levels. In particular, there is now a regular stream of news stories on our website and updates via social media, alongside increased liaison with the Office of External Affairs and Communications, the Strategic Partnerships Office and the colleges about wider dissemination of stories where appropriate.

Recommendation 2. The Department is encouraged to help the University in highlighting its successes to funders and society at large by defining and articulating its brand and communicating its unique strengths.

There is a paragraph in the full report which makes the context of recommendation 2 clearer:

> The panel encourages the University to highlight and celebrate the impressive impact on the discipline and society made by the Department. To help the University in this task, the Department is encouraged to better communicate its unique successes, especially the benefits of its light-touch strategies for commercialisation.

'Commercialisation' may not be the best term to use here, since some of our most impactful activities involve establishing new charities (e.g. Raspberry Pi) and not-for-profits (e.g. lowRISC). The University's liberal approach to IP and its use of very unrestrictive employment contracts is of great importance to CST and a major factor in our success in recruitment and collaborating with industry. In general, we do not focus on obtaining revenue for the University in the short-term, but on maximizing the impact of our research and other activities, firmly believing that this is in the long-term interests of the University. In this light, recommendation 2 is fundamental but not straightforward. In our initial response to the review, we concentrated on the practical steps. Communicating the 'brand' is a considerable challenge, perhaps especially in formal documents, but celebrating individual successes is a prerequisite to doing that, as well as useful in its own right, so we are making progress. The collaboration with Nokia Bell Labs is a particularly good example of innovation in a relationship with industry which is being highlighted by the University.

Professional Services Staff

Recommendation 4. The panel recommends recruiting more academic-related staff (possibly supported by increased return on entrepreneurial activities to the Department from the University) to lessen the administrative workload of both academic and professional services staff who work at and sometimes beyond capacity.

At the time of the SRR, we had about 26 FTE professional services staff: to put this in context, the number had barely increased since 2010 (when we had 25 FTE) while the number of postdocs had more than doubled to over 100. We currently have 28.8 FTE, plus four other members of staff whose roles are associated with individual projects. In our response to the review we described initial plans, which were refined as we implemented them. There has been considerable restructuring of our professional services staff (as some senior staff have retired or left) so that they are now more clearly organised into teams and none of them today works in isolation. This has been more important than the slight increase in numbers. Our aim is that each PSS team is closely associated with at least one member of academic staff, either via a specific role or a committee chair. The intention is that this supports the members of PSS and improves

information flow.

The most important part of the restructuring has been to create a Research Strategy Team, currently with four core members (2.7 FTE) led by the Research Strategy Manager and additionally comprising the Digital Communications Coordinator, a Research Strategy and Industry Coordinator and a Research Strategy and Industry Administrator. We expect to recruit to one or more additional positions shortly. Some of these roles are entirely new, others are revised versions of previous roles. Funding comes from a range of non-Chest sources. The team provides support both for external relationships and for research administration, complementing the work of the Department's Finance team. Since this has only been in place since November 2019, when the Research Strategy Manager started, it is too soon to see the full effects, but it has already been very helpful. For instance, we have been able to offer more support to applicants for ERC and other funding by giving more input in the preparation of project proposals and recruiting and running mock interview panels. This, we believe, has been a factor in our recent funding award successes and it has certainly been greatly appreciated by the staff involved.

The Research Strategy Team also provides structure and support for managers of individual projects. We see an urgent need to recruit more project managers for the large-scale funded projects in the Department, and the Research Strategy Team will make it easier to do this, especially when the funding from a project is insufficient for a full-time role. The team will also help support Research Software Engineers who can be funded from a combination of individual projects and other sources (e.g., the Department's share of overheads).

We would like to give permanent positions to the core members of the Research Strategy team, but are apparently not permitted to do this currently, because of the sources of funding. We have been lucky to recruit exceptional staff despite this, but the short-term nature of the positions is a source of concern to several of them.

Complex HR processes (especially when creating new roles) and the extreme overload of HR personnel, especially at School level where resource is clearly insufficient, has slowed progress to some extent, and naturally this was not helped by the restrictions on hiring due to the pandemic.

Departmental Culture

Recommendation 3. The Department is advised to carefully manage the impact of any further growth on its internal culture.

The lightweight consultation described in our initial response to the review has continued and has encouraged us to rethink practices to improve inclusivity when members of the Department are feeling marginalized. A recent development has been to create the roles of Director of Undergraduate Education and Director of Postgraduate Education, each with a number of Deputy Directors. This was partially a response to the stresses of the pandemic, which exposed the need for a role structure that was more resilient and better buttressed. These roles will make responsibilities on the main teaching committees clearer. We hope they also provide better support for the senior members of professional services staff while reducing the load on the Head of Department team, which had to fill in multiple gaps that appeared during and after lockdown.

Recommendation 5. The Department is encouraged to develop a workload model to distribute administrative, outreach and teaching loads fairly.

The workload committee described in our original response to the SRR made an initial report at the

Departmental 'Offsite' meeting in June 2019. Though there was very little support for a complex stint system, there was general agreement that we needed much more clarity and transparency. We decided not to attempt to calculate any general trade-off between teaching, research and administration since UTOs usually need to be involved in all aspects. The aim is for a very lightweight model, but we only achieved a partial implementation in 2019-20 before the pandemic made a mockery of many of the assumptions we were working to. The restructuring of academic roles described above helps put us in a stronger position for 2020-21. The workload committee has started to meet again and we will review progress regularly.

Recommendation 7. The panel encourages the Department to foster early collaboration and communication between faculty and PhD students and reflect on the integration process, including the collaboration structure, engagement and support, in order to ensure the satisfaction and well-being of its graduate student population.

A number of measures were actually being introduced at the time of the review and more were put in place shortly afterwards, as described in our initial response. Responsibility for this has been clarified as part of the job of the Deputy Director for Postgraduate Education (Researcher Development), one of the new roles mentioned above. The rapid increase in PhD student numbers may make this more challenging but could potentially mean there was more of a cohort and reduce individual isolation. Of course, the Covid-19 restrictions are creating new challenges.

Comment by the General Board: The Secretary of the Senior Tutors' Committee suggested that new appointees to the Department should be encouraged to undertake College responsibilities alongside University duties.

We agree that it is essential that the colleges have a good connection with the Department, especially given the continuing extremely high demand for undergraduate places which has forced us to continue in numbers management. However, there is a tension between undertaking College responsibilities and the excessive workload that the SRR noted. Settling into the University is challenging for staff who come from outside Cambridge and taking on College responsibilities too early can be problematic, especially in colleges which require a minimum level of supervision hours. Nonetheless, five of the ten new appointees to the Department since the SRR now have a College affiliation and we expect more to take up Colleges roles as they become more established. Indeed, a number of those appointed earlier have recently taken up College responsibilities.

Studentships

Recommendation 8. The panel advises the Department to optimise its return on investments from their various industrial links through spin-outs, collaborations and consultancy to fund studentships, for example for applicants from developing countries to advance their outreach efforts.

After discussion with the secretariat, Recommendation 8 was interpreted as concerning underrepresented groups in general. It is therefore discussed as part of Recommendation 9.

Recommendation 9. The University is urged to do more to support the Department in their efforts to increase the number of studentships.

Our PhD student intake has increased very rapidly over the last two years, from around 25 students a year to 50 this year. The main drivers have been additional funding, our involvement in the CDT in AI4ER and the new members of staff. With excellent support from CUDAR, there has been a substantial increase in

philanthropic support from industry for PhD studentships and, to a more limited extent, for Masters' studentships. The DeepMind studentships offer specific support for underrepresented groups. We believe that MPhil studentships are a very effective form of outreach, and hope to increase the number of available studentships.

PhD studentships relating to interdisciplinary activity have increased: in addition to AI4ER, we have two ESRC-funded students. Given the number of UTOs and their overall level of activity, we would appreciate more University support to sustain this increase and eventually increase the number of PhD students to be more in-line with our international competitors. We note that funders often look for guarantees of PhD studentships as a contribution when proposals for large grants are evaluated, and our ability to do this at Departmental level is very constrained. Similarly, a moderate amount of University support to guarantee some PhD studentships for new UTOs would make start-up packages much more attractive. Again, we can only do this to a limited extent at Departmental level. A proper mechanism for guaranteeing studentships and therefore making early offers would likely cost the University relatively little – yet it would have a hugely beneficial effect on our efforts to obtain funding and recruit the best staff. With financial reform, we would eventually expect to be able to do this more extensively in the Department, and this might well be the best longer-term option.

Building

Recommendation 10. The panel strongly encourages the University and the Department to engage in a dialogue about the Department's strategic vision for space, co-location with Information Engineering and collaboration with industry.

Comments by the General Board:

There were growing ambitions to have co-located industry/academic space and interest in the development of a 'Digital Campus'.

In the SRR, we set out our vision of a new space that would support

- the Department's expansion in research staff and students (expected to continue as the newer UTOs build up their teams),
- expanded teaching at all levels, and
- enhanced collaboration with other departments, companies and third sector organisations.

We would not call this a "Digital Campus" but were happy to see the supportive sentiment. We recognise, however, that there is little prospect of an extension or new building in the current financial climate. We note that the West Cambridge Master Plan left insufficient space for a cost-effective extension so, although plans were drawn up in 2016/17, the extension option was not pursued. We also note that the plans for a West Cambridge Innovation District do not so far address the needs we have, since we require space for researchers from industry and third sector organisations to collaborate with us (and each other) in the same building. We are aware of plans for Information Engineering to move to West Cambridge and hope that this can be accomplished speedily, but this does not help address our main needs for space.

The Covid-19 crisis may give us an opportunity for a radical rethink of what the workplace and teaching space means in a Department like ours. Such a rethink would allow us to work in the current building for another five years despite our increasing numbers. For those staff who are able to work in a highly productive way at home, the Departmental workspace could be reconfigured and reimagined. Staff and research students could come into the Department specifically to focus on collaborative activities: we could provide a more welcoming and enabling environment for those to take place and widen the scope for

collaborative working. Similarly, many students have told us that they prefer recorded lectures to live ones (even those that were created very hurriedly last year). This suggests we might accelerate our existing progress towards increasingly interactive teaching and focus on providing that in the Department, blended with online lectures. We are in the process of converting our former library into flexible teaching space, but we could go further. For instance, it might be possible to convert the smaller of our two Lecture Theatres (which is in any case limiting the numbers of our undergraduates) into an area for collaborative project work – ideally one suitable for activities involving other organisations, inside and outside the University.

While this sort of conversion of our existing space will be expensive, it could be a plausible philanthropic target. However, it will be much more complex to work out what such collaboration space would need to look like to support our research and teaching needs in the longer-term. This vision would also require improved infrastructure on the West Cambridge site in order to be fully successful – for instance to support groups meeting for lunch and after work. We are happy that consultation about West Cambridge developments is improving, in particular the Shared Facilities Hub, but feel that there is considerable further scope for better communication.

While we believe the measures outlined above would allow us to fit into our current building for about another five years, we would like the University to identify expansion space or a new location for the Department soon. Otherwise, we fear our long-term future will be severely compromised by lack of space.

Concluding remarks

When the Board originally considered the SRR, a summarising comment was:

The Board noted that the University would potentially need to provide more support and infrastructure to enable the Department to expand and flourish.

The Department has been a major beneficiary of the University's enlightened IP policy and the freedom it gives staff to develop connections and secure research impact. (We have academic staff who openly credit the IP freedom with their decision to turn down offers from other world-class institutions and build their research groups here, and industrial collaborators who credit it as helping their decision to collaborate with us.) To take full advantage of this, the Department needs more freedom in financial matters in order to flourish and this should eventually lead to greater financial return to the University. As we have discussed, this Department has made rapid progress towards a vision of growing modern computer science – especially AI – across the University, rediscovering and re-energising the original idea of the Computer Laboratory. (When Maurice Wilkes and his team built EDSAC, one of the earliest modern computers in 1949, they did so with the aim of creating a general use computer that could be accessible by, and useful to, as many researchers as possible.)

In our initial response to the SRR recommendations, we explained:

> We would like to seek philanthropic donations to support a transition to a new building which supports our departmental vision of a hub, bridging education at all levels, with creation of computer science innovation and collaborative activity with industry, government, and third sector partners. A significant increase in space is essential to this vision, to enable effective collocated collaboration around teaching, research and innovation with diverse partners, and the scale of impact and delivery which matches Cambridge's capability and ambition for the coming decades. We see piloting new models of industry engagement with research, as far as is possible in our current building, as a priority to demonstrate how larger scale activity could work, and to generate revenue which will support our both current needs and future evolution.

We believe that the need for this vision has only increased. We want to pursue it, but we need a commitment that we will have adequate space available to be able to do this.