Early Teaching and Research in Computer Systems at the University of Edinburgh

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Abstract

In the 1960s many UK Universities created new academic departments devoted to undertaking teaching and research in subjects involving the design, creation and use of computers. The Department of Computer Science at the University of Edinburgh came into being in 1966 when the activities of its Computer Unit, formed in 1963, were spilt into academic work in the Department and computing service provision in the Edinburgh Regional Computing Centre. This paper describes some of the Department's activities in postgraduate and undergraduate teaching and research in the design and implementation of computer systems hardware and software from its early beginnings until its absorption into the Division (later School) of Informatics in 1998.

1 Creation of the Department of Computer Science

In the late 1950s and early 1960s computing was becoming a significant requirement of much research in the natural sciences and in engineering. Universities were providing central services on an increasing scale. Among them was the University of Edinburgh, which in late 1962 advertised the post of Director of its planned Computer Unit. Sidney Michaelson was appointed in December and took up his post on the 1st of April, 1963.

Prior to his appointment at Edinburgh, Sidney had been a lecturer in Mathematics at Imperial College London where his research on numerical analysis led him to work with colleagues on the design and construction of a computing machine. Although the only technology available to them was very elementary (Post Office relays and uniselectors), they were able to build a working system, the Imperial College Computing Engine [15]. As part of the design they invented a technique, subsequently known as microprogramming, that has become a cornerstone of the design of almost all modern digital computers.

The responsibilities of the Edinburgh Computer Unit were to provide a computing service, to teach about computing, including what became known as Computer Science, and to do research in that subject. Joining Sidney in this venture were David Rees, Peter Schofield, Mike Osborne and Alex Wight. They were originally based in rooms loaned by the Chemistry Department but moved at the end of 1963 to No 7 Buccleuch Place. To provide a computing service, the University had committed to obtaining computer power as a remote batch service from the Atlas computer[1] at the University of Manchester. Atlas was inaugurated on 7th December 1962 and was, at the time, the most powerful computer in Britain. Although the University of Manchester had every good intention, the practicalities of providing a satisfactory remote service via a Post Office landline between Edinburgh and Manchester proved to be very difficult. In fact it turned out to be easier to send the punched paper tapes used for input to Atlas to Manchester via British Rail.

[1] https://ethw.org/Milestones:Atlas_Computer_and_the_Invention_of_Virtual_Memory_1957-1962

Edinburgh users discovered that the delay between submitting their tapes and receiving results was very variable, often stretching to more than 3 weeks. Naturally, this led to acrimony towards the Computer Unit, so an operator was seconded to Manchester to ensure that Edinburgh jobs received their allocated 15 minutes per day of Atlas compute time. In Manchester Sidney acquired a reputation for fiery outbursts in the face of the many difficulties which beset this venture but ultimately both sides developed a mutual and lasting respect, so much so that Sidney was one of the first external examiners for the Manchester BSc in Computer Science degree.

Nevertheless, it became quite clear by the beginning of 1964 that Edinburgh would need its own computer if Edinburgh users were to have an adequate service. A request was therefore made to the University Grants Committee (UGC) for £600,000 for a suitable machine and to the Government's Department of Scientific and Industrial Research (DSIR) for funds to investigate time-sharing systems. The DSIR responded rapidly, saying that such an investigation was not research, so refused to fund it. However, Edinburgh was not the only university that had come to realise the scale of the costs of equipping and running a computing service and their requests led the UGC to set up, with the Research Councils, a committee chaired by Brian Flowers, at that time Langworthy Professor of Physics at the University of Manchester, to investigate 'the provision of computers for Universities and Research Councils'. The Flowers Committee took evidence from many Universities and recommended that about £7M should be spent each year for several years to equip the universities properly. The Treasury eventually agreed to a lesser but still sizeable figure that allowed several universities to be provided with English Electric KDF9 computers. The Flowers Committee also recommended that there should be a permanent committee (instantiated as The Computer Board) to oversee the distribution and spending of that money.

For Edinburgh, the recommendations were that the academic and service activities should be separated and that Edinburgh should provide service to a (not very clearly specified) Region. So that people would still be able to run their Atlas Autocode (AA) programs on the KDF9, Harry Whitfield, Paul Bratley and David Rees wrote (in AA) an AA compiler for the KDF9, Edinburgh's first foray into systems work. This project involved using the Atlas computer at Chiltern[2] and Glasgow University's KDF9, since the Edinburgh KDF9 had not yet arrived. Peter Schofield and Alex Wight contributed to later versions. Flowers also took note of the interest of Edinburgh in time-sharing, so his recommendations included giving Edinburgh some responsibility for the investigation of time-sharing systems and services. This ultimately led to the creation of EMAS (section 2 below).

The new structure came into being on 1st January 1966 with the creation of the Department of Computer Science and the Edinburgh Regional Computing Centre (ERCC). Sidney became Head of the Department and Dr G E (Tommy) Thomas, an early Manchester computing pioneer who was about to leave ICI's management computing service, was recruited to be the Director of ERCC. ERCC was provided with an English Electric KDF9 mainframe[3].

Sidney was appointed Professor of Computer Science in 1967 and continued as Head of Department until 1975 when he was succeeded by Peter Schofield. Peter's naval experiences undoubtedly influenced the way he ran the Department, steering a steady course and running not just a tight ship, but also a happy one. Non-professorial heads were unusual in those days but Peter commanded the respect not only of his professorial colleagues but also other heads of departments and the staff in the Faculty office.

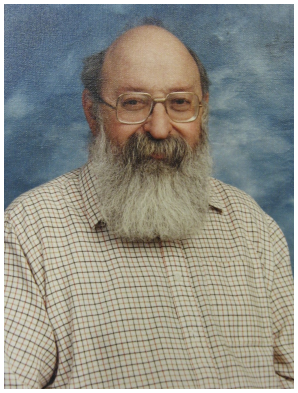
By the early 1980s Peter felt it was time for him to relinquish the Headship of the Department but

[2] https://www.chilton-computing.org.uk/acl/overview.htm

[3] Much of the above text is based on a draft, unpublished document prepared by Sidney in 1988. See also [1]

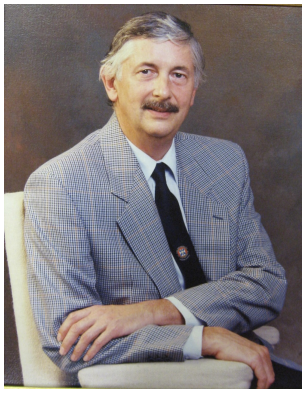
no candidate was forthcoming from among the professors in the Department, all of whom, apart from Sidney, held personal chairs in theoretical topics. It was therefore decided that an appointment should be made to a second established chair. Sidney encouraged Roland Ibbett, then a Reader in the Department of Computer Science at the University of Manchester, to apply. Roland had been a major contributor to the MU5 project at Manchester [7] and he and Sidney had met regularly as fellow members of the British Computer Society's Board of Examiners. Roland took up his appointment on 1st July 1985 and succeeded Peter as Head of Department in 1987.

In 1994, Roland was appointed as a Vice-Principal of the University but continued as Head of Department until 1995, with Gordon Brebner, as Deputy Head of Department, acting on his behalf until 1995 when Gordon became the last Head of Department. In 1998 the Department ceased to exist as a separate entity and became part of the Division (later School) of Informatics, headed initially by Professor Alan Bundy. The Department of Artificial Intelligence, the Centre for Cognitive Science, the Artificial Intelligence Applications Institute, and the Human Communication Research Centre were also absorbed into the Division of Informatics.



Sidney Michaelson
1966-1975

Peter Schofield
1975-1987



Roland Ibbett
1987-1995

Gordon Brebner
1995-1998

Heads of the Department of Computer Science 1966-1998[4]

2 The Edinburgh Multi-Access System (EMAS)

Although the DSIR had refused to fund the investigation of time-sharing systems, the Department of Trade and Industry (DTI) offered £250,000 to support this work, subject to matching funds being obtained from industry. English Electric (EE) agreed to provide the necessary £250,000 and Dr Thomas persuaded the DTI to provide some additional money to enhance ERCC's service machine so that it would be able to support time-sharing. Before the project was completed however, EE was pressured by the Government into a merger with International Computers and Tabulators (ICT). The new company, International Computers Ltd (ICL), honoured the EE agreement but insisted on sending more and more people to work on the project to such an extent that it became unmanageable. As a result, after 4 years the University had a recently delivered machine with EE's batch processing operating system (the Director) but not a multi-access system.

[4] Images copyright of the University of Edinburgh

All was not lost, however, The agreement having come to an end, a new project group was put together between ERCC and the Department of Computer Science (DCS). By 1971 this group of about 9 people that included Colin Adams, Bill Laing, David Rees and Alex Wight, led by Harry Whitfield, had produced the Edinburgh Multi-Access System (EMAS) [16] running on an ICL System 4/75. EMAS was written almost entirely in the Edinburgh IMP programming language, a development, mainly by David Rees, of Atlas Autocode. EMAS had several features that were advanced for the time, including dynamic linking, multi-level storage, an efficient scheduler, a separate user-space kernel ('director'), a user-level shell ('basic command interpreter'), a comprehensive archiving system and a memory-mapped file architecture.

EMAS was subsequently re-implemented to run on an ICL 2900 computer, mainly by David Rees (DCS) and Peter Stephens and Keith Yarwood (ERCC), and later by ERCC staff to run on various other systems that were used to support Edinburgh University's central computing service. Even though slowly superseded by Unix in the late 1980s, as long as it was available, EMAS remained the preferred operating system for a significant number of Edinburgh users, including Sidney himself. The last machine running EMAS was finally switched off in 1992, the year after Sidney's untimely death.

3 Computer Science Teaching

Teaching began in 1964 with the introduction of a Postgraduate Diploma in Computer Science. Undergraduate teaching began in 1965 with the setting up of the Computer Science 1 course, and the acquisition of the Department's first dedicated computer, a DEC PDP-8 (one of the first in the UK), but it was 1968 before a follow-on course, Computer Science 2 was introduced. Computer Science 3 followed in 1970, while in 1971, the year in which the Department moved into the James Clerk Maxwell Building at the King's Buildings campus, the first undergraduate degree, in CS & Mathematics, was created. With the creation of Computer Science 4 in 1972, the Department was able to offer a Single Honours Computer Science degree starting in 1973.

Like numerous other degrees in the Science Faculty, students in years 1 and 2 took three full year courses, one in their chosen degree subject, one in mathematics and one other. For many years Peter Schofield taught CS1, a job few others were keen to do. He had great skill in presenting topics in a way that made them seem obvious. Peter Robertson, one of the first graduates of the Computer Science BSc, remembers the way he taught recursion without mentioning the word until the idea had appeared as something quite ordinary and unremarkable.

In the Honours years, years 3 and 4, students took term-length modules, some of which were prescribed, some of which were optional. Despite his background in mathematics, Sidney Michaelson was an engineer at heart, so the CS BSc degree included a lot of practical work, not just in terms of programming but also involving hardware. Not only did final year students undertake a significant major project, two of the third year modules were themselves major practicals, one of which was (appropriately) a microprogramming exercise using specially developed hardware. By the mid 1980s, however, not only was this hardware becoming unreliable but the Computing Officer responsible for the project left for a job in industry. At the same time, employers nationally were increasingly demanding that computer science graduates have experience of team working. At Edinburgh, Roland Ibbett persuaded his colleagues to replace the microprogramming project with a group System Design Project. Students were assigned to teams of half a dozen or so, each with a project supervisor and each being required to design and implement a system involving both hardware and software that would satisfy the set of requirements that

they were all given. During the morning of the final day of the project each team gave a demonstration of their system to a small group of project supervisors and visiting industrialists. In the afternoon each group gave a “marketing" presentation to the entire class.

In 1988 a related innovation intended to give students "real-world" experience, was the creation of Tardis. Tardis was a computing service run by students for themselves using, initially, a GEC63 computer, contained mainly in a large blue box, that would otherwise have been destined for scrap. The idea for Tardis arose from discussion between Brian Tompsett, then a CS lecturer (and avid Dr Who fan) and John Butler, the Computer Science Service Manager. The students were told that they could make whatever use of it they liked, subject to one rule: they were not to cause any grief to the Service Manager. Tardis ran very successfully for about 8 years, providing students with direct experience of managing systems. This greatly appealed to potential employers and was specially commended in a 1994 Teaching Quality Assessment report as an activity meriting promotion as an example of best practice. Eventually the services it provided became commonplace in domestic network contracts and in student halls of residence, so Tardis no longer provided a unique service and eventually succumbed to this redundancy and to the growing threat from cyber attacks.

For their regular coursework assignments, students in the Honours years in the 1980s had access to a laboratory of 60 home-grown, networked Advanced Personal Machines (APMs), affectionately known as Fred Machines, in honour of Fred King, the Computing Officer responsible for their design and production. The origins of the APMs were in a research project that aimed to achieve three M’s (1MHz clock, 1MB memory, 1Mb/s network connection), based on the use of Motorola 68000 processors. By the end of the decade the APMs were becoming unreliable however and Fred himself left, so the Department invested heavily in Sun Workstations.

4 Computer Systems Research

In 1994 the Computer Systems Group, precursor of the present-day Institute for Computer Systems Architecture, defined itself in the first of a series of Technical Reports[5] as being concerned with “aspects of the subject which concern the design, capabilities and performance of actual computer systems" [6]. That report reviewed some past systems research projects in the Department and surveyed the then current interests of group members. Likewise, this paper presents some highlights of computer systems research undertaken within the Department of Computer Science but cannot claim to be comprehensive. Among other topics described in [6] are work on operating systems [2], sparse vector processing [9], human factors in computer system design [13], database systems [17] and performance modelling [5] [12].

4.1 Stylometry

In the early years of the Department, Sidney continued to pursue research on numerical analysis along with Mike Osborne. In the 1970s he became interested in applying computers to stylometry and worked with the University Chaplain, Andrew Morton, on a statistical study of the usage of words in literary texts, in an attempt to resolve problems of authorship and chronology [11]. They used studies of word order within sentences to cast light on the authorship of texts ranging from the Bible and the Iliad through Elizabethan and Jacobean drama to modern criminal ‘confessions’.

[5] https://informatics.ed.ac.uk/icsa/research-highlights/history/the-computer-systems-group

4.2 VLSI

In the 1980s the development of integrated circuit technology spurred Sidney to return to his earlier interest in computer hardware. In 1981 he was Organising Chairman for a highly successful initial conference on Very Large Scale Integration, 'VLSI 81', held in Edinburgh. In 1982 he founded a new Working Group on VLSI for the International Federation for Information Processing; this became one of IFIP's most active groups, regularly organising workshops and conferences. Working on VLSI with Sidney were David Rees and John Gray. Earlier, in 1980, with Irene Buchanan and Peter Robertson, John Gray had founded Lattice Logic Ltd, a company that pioneered silicon compilation. In 1989, along with Tom Kean, an Edinburgh Computer Science BSc and PhD graduate, he founded Algotronix, a company that developed a Field Programmable Gate Array based on Tom Kean's PhD project.

In 1993 Algotronix was taken over by Xilinx, a USA-based company that was itself taken over by another American company, AMD, in 2022. Among those at Edinburgh who worked with Xilinx was Gordon Brebner, who later (in 2002) moved to California as a Xilinx employee. Gordon graduated from Edinburgh with a Computer Science BSc in 1979 and stayed on to study for a PhD, awarded in 1983 for a thesis entitled "Parallel Computation on Sparse Networks of Processors". Gordon proved himself to be very much a computer science polymath, with interests over the years ranging from computational complexity through computer communications and parallel computing to VLSI design and programmable logic.

In the late 1990s several members of the Department contributed to the work of the Institute for System Level Integration (ISLI). ISLI was a collaborative venture between Edinburgh, Glasgow, Heriot Watt and Strathclyde Universities. It was created at the behest of Scottish Enterprise (a Government agency) in response to an inward investment by Cadence Design Systems of San Jose, California, a leading electronic design automation software and design services company. Based in Livingston, ISLI offered a one-year MSc in System Level Integration and an EngD programme, both designed for graduates in electronic engineering, computer science and other relevant disciplines. ISLI operated very successfully until a global recession in the semiconductor industry in the early 2000s led to its closure.

4.3 Computer Graphics

Some of the graphics software used in the development of VLSI design tools in the Department derived from software created by Eric McKenzie to support the undergraduate Computer Graphics course. This course was started in the mid 1970s and was always one of the most popular CS4 courses. Some features of the course software were also adapted for use by other departments in the University running interactive graphics programs on EMAS.

Research in Computer Graphics took off when Eric McKenzie took on Martin Reddy as a PhD student. Martin's research led to a close working relationship with vision psychologists in the Department of Psychology. They had established an Edinburgh Virtual Environment Laboratory (EDVL) that eventually transferred to Computer Science and then transformed into the Edinburgh Virtual Environment Centre (EdVEC), a joint venture between Computer Science and ERCC. EdVEC conducted both research and commercial projects in Motion Capture and Photo-realistic Rendering of real scenes for interactive experiences. Reddy's PhD experience [14] led him to SRI International and thence to Pixar Animation Studios where he was a CGI software lead on several Academy Award-winning movies. Much of his work appears in [10].

Prior to any of this work in VLSI and Computer Graphics, John Oldfield had established, in 1966, a UK Science Research Council funded Computer-Aided Design Project that was later absorbed into the Computer Science Department [1]. John left Edinburgh in 1974, moving first to Swansea University College and later, in 1978, to Syracuse University where he worked mainly on VLSI design[6].

4.4 Computer Architecture

Roland Ibbett's experience of teaching computer architecture had led him to believe that the workings of systems such as the Tomasulo algorithm, originally used in the IBM System/360 Model 91 computer and subsequently used in a variety of microprocessors to control the movement of operands between programmable registers and parallel arithmetic units, could best be explained by means of a dynamic visual demonstration. This idea came to fruition in the early 1990s with the design and development of HASE, a Hierarchical computer Architecture design and Simulation Environment that allows for the rapid development and exploration of computer architectures [3]. HASE input files are used to create both a screen image of the architecture and a simulation model. When a simulation is run, HASE produces a trace file which can be used to animate the screen image so as to show data movements, parameter value updates and state changes. HASE has been used to support a number of research projects and numerous student projects and virtual laboratory practical exercises.

Also in 1985, Nigel Topham joined the Department from Manchester where his PhD project, supervised by Roland Ibbett, had involved the creation of a parallel vector processing system. At Edinburgh he investigated a variety of architectural techniques aimed at increasing both the performance and energy efficiency of individual and multi-core processors. He also worked as a processor designer with several industrial concerns including ACRI, a French supercomputing startup, Siroyan and ARC International plc. At ARC he led the design of the ARC-600 embedded processor, subsequently implemented widely in many billions of chips, the second most-widely used embedded processor architecture after ARM[7].

4.5 Parallel Computing

Prior to Roland Ibbett's appointment, he had given a lecture entitled "The Gigaflop Quest" in the James Clerk Maxwell Building, which the Computer Science Department shared with the Mathematics and Physics Departments and Computing Services (the successor to ERCC). This lecture had attracted the attention of several members of the Physics Department, especially Professor David Wallace. Some of his colleagues were already using various DAP computers and a few years later David's group acquired a Meiko Computing Surface, a Transputer based system. They were struggling with the task of managing it, however, and at a meeting with Peter Williams, Deputy Director of Computing Services, Roland suggested that what was needed was a unit dedicated to parallel computing, to be organised as a joint venture between the Departments of Physics and Computer Science and Computing Services. They put this proposal for an Edinburgh Parallel Computing Centre to David Wallace and persuaded him that he should be its Director. EPCC went on to become the UK's leading academic high-performance computing centre.

In the Computer Science Department, several academic staff had interests in parallel computing. Among them was Murray Cole who graduated in 1984 with an Edinburgh BSc in Computer Science and later with a PhD awarded for his work on algorithmic skeletons for structured management of parallel

[6] https://news.syr.edu/blog/2009/07/31/college-mourns-passing-of-professor-emeritus-john-oldfield
[7] https://www.synopsys.com/designware-ip/processor-solutions/arc-600-family.html

computation [4], with Gordon Brebner as his supervisor. After spending three years at the University of Glasgow, he returned to Edinburgh as a Lecturer in 1990 where he continued his research interests in parallel programming models, emphasising approaches which exploit skeletons to package and optimise well known patterns of computation and interaction as parallel programming abstractions.

In the early 1990s, the ALAMO project (ALgorithms, Architectures and MOdels of computation) [8] brought together many of those in the Department who had interests in parallel computing, computer architecture and simulation: George Chochia, Paul Coe, Murray Cole, Pat Heywood, Todd Heywood, Roland Ibbett, Rob Pooley, Peter Thanisch and Nigel Topham. The project aim was to investigate the scalability and efficiency with which the Hierarchical PRAM model of parallel computation might be implemented on realistic parallel architectures.

5 Conclusion

During much of its existence as a distinct entity, the Department of Computer Science at the University of Edinburgh rightly enjoyed a stellar international reputation for its contributions to theoretical computer science. This tended to overshadow much of the pioneering work of colleagues whose interests lay in the area of computer systems. This paper is an attempt to redress this situation, though it is inevitably an incomplete record - apologies to those whose contributions have not been included. Further information can be found in the Computer Systems Group Technical Reports[8] and in the Edinburgh Computer History Project website[9].

Acknowledgements

This paper could not have been written without the work of all those involved in teaching and research in computer systems during the lifetime of the Computer Science Department. The author is especially grateful to Gordon Brebner, John Butler, Murray Cole, Eric McKenzie, David Rees and Nigel Topham and, posthumously, to Sidney Michaelson for their contributions to this document. Thanks are also due to Chris Williams for his encouragement and helpful criticism and to George Ross for his preservation of historical documents.

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