UK COMPUTING RESEARCH COMMITTEE

Royal Society Fruits of Curiosity

Response from the UK Computing Research Committee

Professor Muffy Calder, Chair UKCRC
University of Glasgow
muffy@dcs.gla.ac.uk
Professor Ursula Martin, Vice Principal
Queen Mary University of London
Ursula.Martin@qmul.ac.uk

UKCRC

The UK Computing Research Committee is an Expert Panel of the British Computer Society, the Institution of Engineering and Technology, and the Council of Professors and Heads of Computing. Its members are leading computing researchers from UK academia and industry. We respond in that context, though our responses may be more widely applicable.

Preamble

Few technologies, if any, have had a greater impact on the everyday life of humanity than ICT, Information and Communication Technology. The first stored-program computer, the Turing Machine, was invented by the British mathematician Alan Turing as a thought-experiment, and published in the British philosophical journal Mind. It proposed a law of computation that still lies at the basis of the subject. That it is only 60 years since the Manchester University “Baby”, the first actual computer to run a program stored in its electronic memory, underlines the staggering speed with which this technology has moved from speculative research to global impact.

Although the internet can be traced back to the early 1960s, it is only 20 years since it entered the consciousness of the general public as a result of a British computer scientist, Tim Berners Lee, inventing the world-wide-web. Yet already the web is a major vehicle of science and commerce, and of growing importance to government. Today most of the computing power on the planet is based on designs licensed from ARM, a medium-sized British company based in Cambridge, whose business has grown over the same 20 years from nothing to ten million microprocessor shipments a day.

The central role of ICT in everyday life is clear. For better or worse, every train carriage is occupied by people talking on mobile phones, listening to iPods, browsing on Blackberries, and absenting themselves from their physical environment to engage in virtual business, family or leisure through the medium of ICT. But these visible devices are just the tip of the ICT iceberg. They rely on an infrastructure of considerable sophistication whose capacity and capabilities are expanding at a stunning rate. And increasingly, this same infrastructure is being exploited to support services for government, health services, science, and pretty much the whole gamut of human activity. Many such applications involve increasing amounts of artificial intelligence, for example search engines, face recognition, or data mining.

The rate of progress of computer technology over its first 60 years has surely been impressive. Today’s computers are a hundred billion times more power-efficient than their early forebears, and a million times faster. Devices can hold a million times more data and communicate a million times faster than they could just 30 years ago, while cost has dropped dramatically. That is just the hardware. Software advances on the back of this staggering progress deliver orders of magnitude more functionality than that of early mainframe computers.

Every tenfold improvement opens up dramatic new applications and markets, provided that it is backed by forward-looking and curiosity-driven research, and there is no sign that the rate of progress is decreasing. Moore's law continues to give us advances in computing power.

Advances in software technology, and the means to construct and manage ever more complex hardware and software systems, mean that advances in computing over the next 50 years are likely to be even greater than those of the last 50 years. No-one can foresee what this will entail: Advanced machine intelligence? A merging of physical and virtual existence? Brain prostheses? Think back 50 years and try to predict mobile phones and iPods from the technology base of the 1960s, and you will see the problem. On a shorter timescale prediction is easier: for example using computer vision and sensors embedded in vehicles, we could, if we were minded achieve a tenfold reduction in road accidents and their associated costs and misery.

What is clear is that computing research is now more exciting than ever, and has more potential than ever to transform the future. The UK must aspire to sustain its position at the leading edge of computing research, if it is to influence how this vital technology will take an ever more central place in the human experience, from the perspectives of both wealth creation and quality of life.

Computing research is a global pursuit, and the UK's research contribution is just one component of the wider whole. The examples of ARM and the web show the difficulty of assessing the ultimate impact of current research, as it can take 20 years for the full impact of new research to become apparent. The 2008 Research Assessment Exercise showed that twenty per cent of UK computing research can be considered world-leading, and almost two-thirds was judged to be internationally excellent. The subject was found to be healthy and growing, and more rigorous, more interdisciplinary, more experimental and more user-oriented than in the 2001 RAE. EPSRC's international reviews of UK computing research have also found the subject to be thriving.

In addition to its current pervasive role, computing also contributes to the intellectual and cultural traditions of humankind. At the abstract level, computer science ideas ("computational thinking") increasingly pervade science, engineering and the humanities, for example philosophy and linguistics. Developments in computer science and technology have created a new vocabulary of concepts, models and metaphors that are finding increasing utility in other disciplines, and in everyday life. Complex systems, for example, are often best understood in terms of the dynamics of the information flows that determine their emergent properties. Understanding user behaviour, and the impact of technology on individuals and society, is a core part of the discipline, embracing psychology, sociology, behavioural economics and ethics.

Computer simulations and models play increasingly important roles in science, engineering, economics, climate modelling and the like. Advances in computing research contribute to advances in modelling, as these models are frequently limited in their fidelity by the efficiency of the computer hardware and software. These are core to the knowledge economy – central to this ambition is access to the most advanced computing capabilities that research can deliver.

Ever more scientific research is now conducted by mining vast databases of experimental results, created either by central capital-intensive equipment, as in particle physics, radio astronomy and earth satellites, or amassed from the results of large numbers of independent experiments as in many areas of biology. UK computing research has already yielded significant advances in e-Science and Grid technology that support this research, but much more remains to be achieved. For all of these reasons, computing research will continue to be vital to progress in many disciplines, and maintaining a vibrant UK computing research capability will yield benefits across the entire domain of academic and industrial research, and in our ability to exploit the knowledge economy to maximum benefit.

The long-term direction of policy for science

1. What role should curiosity-driven research play in the UK science base in the next 15-25 years?

Curiosity-driven research is essential for the UK science base to maintain its competitiveness and creativity. Only curiosity-driven research contributes to the scientific and cultural traditions of humankind. Only curiosity-driven research makes the totally unexpected discoveries that trigger true innovation. Only curiosity-driven research can accumulate the understanding that enables us to meet the 'unknown unknowns' in our uncertain future.

In computer science, curiosity-driven research includes fundamental basic research creating new technologies and new theoretical underpinnings, alongside user-inspired research leading to new applications, and engineering research to understand and create systems which bring the pieces together. A recent report[1] *by the US National Academies on innovation in computing summarised the broader benefits of curiosity-driven research as:*

- *Research has kept paying off over a long period*
- *The payoff from research takes time - 20 years is often mentioned*
- *Unexpected results are often the most important*
- *Research stimulates communication and interaction*
- *Research trains people*
- *Doing research involves taking risks*

2. Which elements of policy for science and innovation over the past 10 years have been successful and should be maintained? Where is there room for improvement?

Since 1997, UK science has enjoyed increased investment from government through RCUK, HEFCE QR and capital funds for buildings and equipment. Computing research has benefitted both from investment in programmes of basic research such as EPSRC's responsive-mode funding, portfolio and programme grants, and from major directed research programmes such as the Interdisciplinary Research Centres, e-science and digital economy programmes.

Computing research has won significant European Union funding in recent years, and it would be good to see similar investment to promote UK-US collaboration, building on the success of initiatives such as the MoD/DoD International Technology Alliance for network technologies.

3. How will increasing support for science in the US, China and elsewhere impact on the UK's international standing and attractiveness as a place to undertake world-class science?

Increase of funding for science in any country must always be welcomed. Science as a whole will benefit by tapping more widely the intellectual potential of a wider constituency of potential scientists. By maintaining the excellence of UK research, we will be able to exploit overseas advances, both for the benefit of science and for the benefit of the country. Many nations are investing in computing research as they see computing as a key enabler to economic growth. In this respect the UK cannot afford to fall behind. Participation by UK researchers in the research of the international scientific community will make more immediately available to UK industry a much larger flow of successful research ideas than those originating in the UK alone. It also seems inevitable that any decline in UK investment, contrasted with increases elsewhere, for example the US or Asia, will impact UK success in recruiting and retaining staff and students.

[1] Innovation in information technology, National Academies Press, http://books.nap.edu/catalog.php?record_id=10795

4. How should science be governed to maximise benefits to society while acknowledging public questions, uncertainties and concerns?

Modern ICT technologies lie at the heart of many innovations in government and policy, and the public have a lively and healthy interest in the capabilities and risks; consider for example debates on ID cards, e-voting, online security, or NHS IT. It is essential that government, policy makers and the public should be able to make informed choices in the light of the scientific and technological issues, and the impact these choices might have. Politicians and government should take the lead: they should have good access to expert advisors and listen to their advice. Thus, as well as government departments having chief scientists, they might consider chief computer scientists, and recruit policy advisers with appropriate technical background.

5. How should we assess the long-term social and cultural impacts of scientific research?

Science is in itself part of the culture of society, at least as important as entertainment, sport or music. Its social impact should be to give the general population a respect for the scientific method: the impartial pursuit of truth and the collection of evidence to decide important questions. The massive availability of misinformation, especially on the web, make this increasingly important. Modern IT and telecommunications have themselves brought about extraordinary changes in culture and society, the result of decades of academic, government and industry research in the UK and around the world, and it is hard to predict what will come next.

Investing in tomorrow's talent in schools, universities and in the FE sector

6. How much progress has there been in the past decade in the delivery, content and assessment of education in STEM (Science, Technology, Engineering and Maths) subjects?

7. What are the future challenges for STEM education at primary, secondary and tertiary levels? How should these challenges be addressed?

The Committee of Professors and Heads of Computing published a study on the IT Labour Market in 2008[2] They showed that, despite the downturn, demand for IT jobs is predicted to rise by 20% over the next decade, in particular for technical and managerial staff. Yet numbers studying computer science in Higher Education dropped by 22% between 2003 and 2006, and numbers taking Computing A level have fallen by almost half in the same period.

Within the school system there has been widespread criticism of the content of the curriculum, and concern over a lack of specialist teachers. Parents, students and some teachers are confused by the difference between computer science and IT (akin to the difference between designing cars and driving them). We recommend the reintroduction of Computing, as opposed to IT, at GCSE level to encourage more pupils to persevere with the subject. At the same time course material and lesson plans can incorporate the principles of computer science into other school subjects. A general skills-based education in IT is also important, but the curriculum is often criticized as being pedestrian, and could be used to bring more awareness of broader issues needed to make informed choices, such as security and privacy. The cultural aspects of science and technology could also be emphasized to attract students into STEM. The enormous interest shown by schools in the cs4fn[3] campaign, run by Queen Mary University of London with support from the research councils and industry, is an indication of what is possible.

More can be done by HEIs, government and employers to promote computing degrees, and identify

[2] http://www.cphc.ac.uk/docs/reports/cphc-itlabourmarket.pdf
[3] www.cs4fn.org

flexible offerings so that elements of computer science can be studied alongside other disciplines, and opportunities for reskilling and upskilling can be provided at undergraduate and masters level. The government policy on ELQs, which means such students are at a disadvantage compared to those entering higher education for the first time, should be reversed.

8. How do we ensure that adequately qualified science and mathematics specialists are attracted into the teaching profession at all levels of education (primary through to tertiary)?

This is a significant issue affecting computing as much as science and mathematics. It is hard to see quick fixes, although the introduction of more interesting and rewarding curricula, and the inclusion of elements of computer science in teacher training programmes for all STEM subjects, might itself make a difference.

Building and sustaining research careers

9. How can we make research careers – within academia or industry – a more attractive option for young people, both within the UK system and from abroad?

10. What sorts of incentives can we develop to keep talented students and postgraduates in science?

11. Does the standard career-track model need to be re-evaluated? Should we take more account of the movement of skilled individuals between academia, industry and business?

The UK research career, with a short PhD, and typically a pattern of short-term postdoctoral appointments, followed by the demands of an academic career combining teaching and research, is often said to be more demanding than the longer timeframe in the US or other European countries. In recent years this has been compounded by the difficulties early career staff, or those who take a career break, face in an increasingly competitive grant funding regime.

For a fast moving field like computing, formal or informal interactions with industry, whether through secondment, or the movement of students, are key in staying ahead of research trends, and are broadly seen as healthy. Research laboratories such as Microsoft and IBM also work alongside universities in training young researchers through mechanisms such as Internships, Visiting Researchers and PhD Scholarship programmes.

Early career fellowships, such as the Royal Society University Research Fellowships, or the more generous European Research Council analogues, are extremely valuable in enabling an academic to establish their own career away from funding pressures, and the overly managerial approaches being adopted by some institutions in response to the RAE/REF.

Science, innovation and wealth creation

12. How can we strengthen science and innovation in all parts of the private sector in the UK, and further improve the exchange of knowledge and expertise between the public and private sectors?

13. How can we improve the scale and contribution of private sector R&D?

14. What initiatives (e.g. tax credits) have been successful or not with regards to supporting innovative businesses in the UK? How can the UK better support business?

UK computing research has benefitted from the presence of world-leading commercial research laboratories, for example Microsoft and IBM, attracted to the UK by our research strengths. Their research is comparable to that in academia, facilitating the movement of researchers between the two *environments and increasing the flow of technology transfer. Government needs to do more to attract inward investment from multinationals: Ireland is an example where tax incentives have worked well. The R&D tax credit scheme is highly regarded by business as a mechanism for stimulating research, and we support the CBI's recommendations[4] for extensions. There is some concern among both industry and academia that the Technology Strategy Board has missed the opportunity to invest in stimulating the transition of research.*

The ecology of research funding

15. How do we maintain an appropriate funding balance between curiosity-led, response-mode research, and more targeted or programmatic funding?

To some extent the implied dichotomy between curiosity-driven research and targeted funding is a false one: big curiosity-driven questions in science, for example searching for the Higgs boson or the moons of Saturn, can require significant investment and planning to answer them. The extraordinary advances in computing over the past thirty years have been the outcome of sustained programmes of research by universities, government and industry, which none-the-less allowed scope for curiosity-driven research within them. Currently, for example, EPSRC funds research in our field through the ICT programme and the Digital Economy targeted initiative, with the former receiving about twice as much as the latter. The RCUK e-science initiative, currently being evaluated, received similar significant investment, and gave UK academia and industry a head-start in cloud and grid computing, an example of how such targeted programmes can create both good science and a healthy environment to benefit commercial progress. Thus we would welcome government investing more in the Grand Challenges of computer science.

A major gap has been the support for major long-lived pre-competitive development programmes which would enable the translation of research: for example experimental software platforms. The use of computers in scientific research has changed, or even eliminated, the boundaries between pure and applied research and opened up a whole new, and much more rapid, route of technology transfer between basic research and applied research. The results of basic research can now be accumulated in the design and evolution of the scientific and engineering tools that are used for commercially successful innovations.

However, while such targeted investment programmes have a significant role to play, we know of no evidence that they contribute more to research impact, quality of life, or the development of trained people, than responsive mode funding. Certainly, well managed responsive mode allocations, driven by scientific judgement rather than bureaucratic assignment processes, encourage a diversity of speculative and risky approaches, with the imagination, drive and prioritization coming from scientists themselves and not from centralised planning. It is vital that funds are retained, despite the downturn, for responsive mode research allocated by peer review.

17. What role should public sector R&D outside the ring-fenced science budget (e.g. departmental spending, government procurement and national laboratories) play in supporting the UK science base?

The all-pervasive role of IT means that many areas of government, for example the NHS or defence, are involved in R&D, and in significant procurement exercises, which have the potential, through investment in the research base, to stimulate significant innovation. Government provides a market, which mitigates the risk to business of investing in R&D. We support the extension of the Small Business Research Initiative, which promotes access to procurement contracts by requiring government departments ring-fence funds for small businesses.

[4] http://www.cbi.org.uk/pdf/20090204-CBI-R&D-Tax-Credit-survey-report.pdf

In particular, smart procurement of ICT systems should require greater use of scientific methods: see for recent example recent reports from the Royal Academy of Engineering[5]. This will both promote UK R&D, giving UK companies a world lead, and produce more dependable ICT systems, saving costs as a result. More generally, smart procurement can include the purchase of IP, which will directly promote UK high-tech industries.

[5] Engineering values in IT, a report from the Royal Academy of Engineering, July 2009 http://www.raeng.org.uk/news/publications/list/reports/Engineering_values_in_IT.pdf