The Future of Computing—Visions and Reflections

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Dedication

"Computing is too important to be left to men"

Karen Spärck Jones, FBA

Emeritus Professor of Computers and Information

Honorary Fellow of Wolfson College

26 August 1935 - 4 April 2007

Karen was to give a talk at the forum but felt too unwell to attend. It was with great sorrow that, days later, we learnt of her death.

She will be greatly missed.

Obituary by Yorick Wilks: http://nlp.shef.ac.uk/KSJ.doc

'The Future of Computing: A Vision' was a senior women's forum, organised by The e-Horizons Institute (University of Oxford) and Women@CL. It ran for two days in late March 2007 and brought together senior women in computer science and related disciplines to consider their vision of the future of computing and what these visions could and should mean for the computer science research agenda. This meeting followed a forum in 2004 on the role of women in computer science, where the absence of female voices in IT appeared as a major topic.[1]

This document is a digest of the themes related to future computing research that emerged from these two days of discussions, beginning with a brief summary of the three talks given as part of the event.

[1] Martin, U., Liff, S., Dutton, W.H. and Light, A. (2004) Rocket science or social science? Involving women in the creation of computing. OII Forum Discussion Paper No. 3. Available at: http://www.oii.ox.ac.uk/resources/publications/FD3.pdf

A discipline of disciplines

One first observation upon the nature of the forum was the diversity of practice that is included in the domain of computer science research and which was represented at the meeting. These different starting points informed the discussions so it will be useful to begin with a brief analysis of this diversity.

Three generic clusters of interest could be identified in the group. These will be characterised here as ‘pure’, ‘applied’ and ‘social impact’, to use labels already manifest in the discipline. In terms of vision, these distinctions were not only recognisable in how they affected priorities and interests, but also in how people orientated themselves towards outside influences and trends.

The pure

The purest computer science is a form of applied mathematics. It concerns the nature of modelling, devising means of abstraction and new forms of expression. It is driven by developments within the discipline and trends in interdisciplinary working, such as modelling biological and chemical processes. Topics are as much determined by individuals’ sense of what is worth investigating as shifts in society and in funding. In its most theoretical form it is as blue-sky as other pure sciences though it is argued that it lacks the inalienable right of disciplines such as astronomy to work without reference to application.

The applied

Much work in computer science can be seen as specialised engineering in that it takes the techniques of computing and an external challenge and produces everything from algorithms to circuitry to software widgets to solve problems and develop new functions. This approach in its academic form is freer than its industrial counterpart to include the design and investigation of new computing approaches and applications for the sake of learning, but nonetheless has a dynamic relationship with the marketplace and the needs of society. In as much as it is driven by what is possible, this aspect of the research agenda is very future-orientated and does much to shape society even as it responds to it. However, it is in turn shaped more strongly by funding initiatives, such as special calls on ‘bridging the global digital divide’ and ‘memories for life’, established to respond to particular social issues.

The social impact

Driven by the effects of the technology coming into use in society, the third generic domain relates closely to the previous one. This field of research includes analysis and critique of the design and implementation of technological solutions and their fit with the lives of individuals and groups. In proposing ways to alter these relationships, developing design approaches and making recommendations, it shares the implicit bettering tendency of other aspects of computer science. It is almost entirely dependent on trends in technology, taking its cue from commercial and social priorities. Although social analyses can be based on blue-sky forecasts, the best are anchored in systematic empirical observation.

Three talks

The two days' discussions were punctuated by three talks. These had been selected to represent different aspects of the discipline while offering snapshots of ground-breaking research. Muffy Calder, Professor of Computing Science at the University of Glasgow, addressed 'Computational Thinking and Interdisciplinary Research'; delving into the relationship between computer science and biochemical modelling. Margaret Martonosi, Professor of Electrical Engineering at Princeton University, spoke on 'Architecting Mobile Systems of the Future: Technical and Social Challenges', using her work on tracing zebra in Kenya as a case study. And Susan Leigh Star, Professor of Women and Gender Studies, and Senior Scholar at Santa Clara University, California, took 'Orphans of Infrastructure: a New Point of Departure' as her theme, in which she looked at the way that any kind of categorisation creates exclusions.

A summary of the key points of each talk follows.

Muffy Calder: Computational Thinking and Interdisciplinary Research

Calder explained her work on modelling and reasoning about biochemical systems and how models could be used in intervention (such as with drug targets). So, in contrast to the trend in interdisciplinary research towards biologically inspired computing, Calder is producing computationally inspired biochemistry, looking particularly at the signalling pathways involved.

The challenge comes because pathways are stochastic, continuous time, concurrent, communicating distributed systems. A signal is indicated by a high concentration of a molecular species. Continuous concentrations are historically modelled by discrete abstractions, whereas Calder is using process algebra to produce models which reflect the continuous process of the actual system.

The models enable Calder to perform new kinds of analysis, while exploring new ways of relating traditional and non-standard modelling. And this hinges on computational thinking, she said. She placed Jeanette Wing's[2] description of these thinking processes at the heart of her talk, as follows:

- what a system does and how it does it
- what are the right abstractions
- what can you leave out, what must be considered
- what are the best representations
- what is the power and/or constraints of the underlying machinery

[2] Wing, J.M. (2006) Computational Thinking. CACM 49:33-35. Available at: http://www.cs.cmu.edu/%7Ewing/publications/Wing06.pdf

- what are the interfaces
- what are the conditions for operation
- what are solutions for similar systems or components

‘One of the most important contributions of Computer Science is computational thinking. I couldn’t have made this move into theoretical biology without it,’ she acknowledged. ‘Computational thinking isn’t just for Christmas or for computers and software, it’s for life!’

She pointed out that working with the disciplines of science, rather than applying computing to computing, involves engaging with systems which exist and which offer the opportunity to do some reverse engineering, rather than with systems which will exist and have to be designed.

She went on to look at the questions thrown up by doing interdisciplinary research. In particular, she explored the issue of following one’s skills set or, instead, developing new specialisations that follow the needs of the research. How does one handle the realisation: ‘I’m an expert in X and have learned a lot about application Y, in order to apply X to Y, but now I see that Z would be more appropriate than X’? Does one change the research area to Z or change the application area to W, which is more amenable to X? There was no easy answer but the question provoked some interesting discussion about seniority, confidence and the nature of enquiry.

Margaret Martonosi: Architecting Mobile Systems of the Future: Technical and Social Challenges

Martonosi works with mobile and wireless computing, exploring new computational models in which sparsely connected and dynamically changing confederations of computer devices collaborate across wide areas to gather information and solve problems. In her talk, she drew from her experiences building the ZebraNet system for wildlife tracking—based on mobile collections of GPS-based sensing devices reporting to mobile base stations—to show how energy provision can be optimised and kit made small enough to avoid intruding.

ZebraNet is an interdisciplinary project combining both engineering and biology research. Martonosi ran through the limitations that placing sensors on zebras imposed upon the project. For instance, where elephants can move around with car batteries strapped to them, zebras will only tolerate a small neckband. And having spent two years designing the neckband to fit snugly so that antennae would stay vertical, best laid plans were upset by the 11th hour discovery that neckbands would have to be loose on the neck. Despite such setbacks, the distributed system of data transmission was highly successful and revealed interesting patterns in the movements and mating patterns of the particular group being studied. (Martonosi discussed later the measures they took to evaluate any distress caused to zebras and their happy conclusion that neither the neckbands nor the system affected them adversely.)

Local experts familiar with the animals had offered information on the regular locations of particular members of the group and this informed the data structure set up to feed information from one animal to another and finally back to a car or plane. Lessons from the project are already being used in a new iteration and have implications for other contexts, such as human peer-to-peer communication, raising issues about security and privacy that were not so critical with zebras.

In this way, Martonosi illustrated a project finely balancing engineering requirements and contextual design. Relating it back to the crowded streets of New York, she gave a sense of the potential social applications of the work. 'Our studies so far point to the promise of this class of large-area GPS-enabled sensor networks. Finally, our study of protocols and their power and energy concerns gives us confidence that our weight limit allows us enough batteries and solar cells to achieve good data homing success rates.'

Susan Leigh Star: Orphans of Infrastructure—a New Point of Departure

Star is a sociologist of science whose research reaches from the work of scientists and those that invisibly support them, in particular women's roles, to the nature of categories and classification. She focused on this last aspect in her talk, looking at how systems that categorise necessarily include some aspects of the world and leave others outside their remit. In doing so, she stressed, the members of these 'residual categories' can become invisible or worse. Residual categories include:

- Not elsewhere classified
- None of the above
- Other
- Not otherwise specified
- Garbage category

She called this phenomenon of being left on the outside 'orphaning' in the context of building infrastructure. Lived residual categories result in peculiar silences, she said: '"None of the above" doesn't mean anything too specific; it is a way of silencing lived experience. It works to create non-people: women, disabled men, men of colour, who do invisible work and have invisible lives. Can we shift the vision of HCI to begin with the disenfranchised? What opportunities does this offer for freedom, compassion, and change?'

She raised a number of ways that something could find itself residual, listed here:

- Residual because the object is unknown.
- Residual because the object embodies two or more categories in schema where only single choice allowed (falling between the cracks).
- Residual because the structure of classification system has a limited choice, and lived experience does not fit any (classic: none of the above).
- Residual because the object is unspeakable (silencing; miscount; passing).
- Residual because the object is too complex or complicated—beyond the technical capacity of system.
- Residual because the object of lived experience is disbelieved by the data collector, respondent classed as 'crazy' or 'disorganized.'

- Residual because science is in flux (e.g. chronic pain moves from a sign or symptom to a disease entity; experiments fail)
- Residual because the data entry clerks are underpaid, bored, disrespected (they make up the results: 'sidewalk surveys'; they lead and collude; just don't give a goddamn anymore).

Then she told the story of the Dionne quintuplets, born in the deep South during the Depression in 1930s USA and the first surviving family of this size. They were made orphans—sequestered by a doctor; their parents allowed to visit only twice a year. Every action of theirs became medical data, written into 'some of the most boring papers ever produced'. The children were a popular cultural icon and a much-visited tourist attraction, used as an image of purity in a number of commercial contexts. They became wholly institutionalised and very profitable to their keepers. 'Would it have been the same for baby boys?' asked Star.

She concluded with some suggestions that she drew from feminist analytics, without applying them specifically to the domain of computer science. We might make orphans the point of departure and reference, rather than starting with the seemingly 'main' infrastructure; use lived experience as our reference; see infrastructure as relational, not absolute, and go from 'not elsewhere classified' to 'queering the infrastructure'.

Following her talk, it took a few minutes for the implications of her suggestions to be applied to the dominant discourse, of formalising. Indeed, the talk could not be classified. Then it resulted in exactly what she was suggesting: it offered a different way of looking at the taken-for-granted and, in the intellectually generous environment of the meeting, it was allowed to turn accepted practices on their heads.

The trouble with visions

As part of considering the future, the group asked: what are the challenges in conceiving a vision for our science?

The first answer was a disclaimer. The event being entitled 'The Future of Computing: a Vision', it was felt necessary to point out that the pursuit of a vision was not an act of prediction, rather a chance to decide what would be desirable. In fact, the ability to predict more effectively was one feature on the wish list, though this was particularly related to applying computer science to modelling behaviour in areas that would benefit from more insight such as patterns in diseases.

Then it was quickly clear that there would be no single vision. As mentioned above, the discipline contains many threads of interest, each with a different orientation to technology and society. Visions related to how the individual saw computing and the nature of their research areas.

Another distinction appeared between how people wanted computing to progress as a research topic and how they wanted to experience it as a member of society. Everyone revealed an interest in the social impact of technology; everyone had their own sense of what would be ethical and desirable. It was the uniting aspect of the group that no one was so fixed on a technical or career view of the future that they couldn't respond to the social issues determining its impact, such as how much control should remain with the individual as—in all likelihood—our tools begin to know even more about us.

The danger of visions cropped up in this context. Visions are not neutral features of the developing discipline. Mark Weiser's[3] vision of ubiquitous computing was cited as a major influence on the last 20 years' development: it recognised how certain technologies were developing at the time, but it also suggested to others ways of employing new mechanisms as they appeared and affected the questions asked by researchers. Visions have a way of progressing from the surprising to the obvious. They can be used by their heirs to justify a direction for research and to affect funding priorities. If they begin as utopian, they can miss some of the social elements that might make them less attractive in the implementation than the imagining. They obscure other choices. In that they often stay within the literature and don't come under political and social scrutiny, they lack interdisciplinary thinking. So it was agreed that visions could be determining in a way that was both an asset and a responsibility.

The nature of visions

But visions are an important part of being a leader and thus senior women have need of them, it was agreed. Adopting a thought leadership role offers the potential to inspire junior researchers and other women, to challenge any male hegemony and to stake a claim for new sources and directions of funding.

Although the strengths of fielding a vision could be identified, it was also felt important to acknowledge that visions are rarely attained smoothly. What looks like a military operation in hindsight is often a series of fits and starts, setbacks and tangles in the pursuing. So having a vision should not interfere with the process of learning, of making mistakes and of finding and following tangents. It was about showing generosity and forgiveness to oneself and one's team.

The value of Grand Challenges (see box 1) as a particular kind of vision was discussed. It was pointed out that a paradigm shift took place in computing during the late 1980s and early 1990s, with Winograd and Flores,[4] Suchman[5] and Brooks[6] all contributing defining visions. Yet they were not working together or even in agreement. Grand Challenges might work to prioritise areas of agreed interest but should not do so in such a way that researchers all have to line up behind one person's methods or a particular doctrine. Enlightened leadership would be key to managing a number of disparate endeavours all tackling related issues without a crippling orthodoxy. And collaboration should be allowed to take a variety of forms. Both collaboration and interdisciplinarity were seen as growing trends, bringing their own opportunities and problems.

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[3] Weiser, M. (1991) The Computer for the 21st Century. Scientific American 265:94-104.

[4] Winograd, T. and Flores, F. (1986) Understanding Computers and Cognition: a New Foundation for Design (Ablex: Norwood/NJ).

[5] Suchman, L. (1987) Plans and Situated Actions (Cambridge University Press: Cambridge).

[6] Brooks, R.A. (1991) Intelligence without Representation. Artificial Intelligence 47:139-159.

In conclusion, pursuing breakthroughs in multiply sited small incremental steps was felt to have advantages, but begged the question: how are they guided? Some kind of vision is important to offer the path. And scepticism drawn from past endeavours could be used to measure direction and progress.

Box 1: Grand Challenges

The Grand Challenges Exercise was established in 2002 by the UK Computing Research Committee (UKCRC), an expert panel of the Institution of Engineering and Technology and the British Computer Society comprising internationally recognised researchers, to discuss possibilities and opportunities for the advancement of computing research, particularly in the UK. Challenges are submitted by the research community to the UKCRC, identifying ambitious, long-term research initiatives that might benefit from some degree of national and international coordination.

Criteria include:

- Being greater than what can be achieved by a single research team in the span of a single research grant.
- Being directed towards a revolutionary advance, rather than the evolutionary improvement of legacy products.
- Emerging from a consensus of the general scientific community to serve as a focus for curiosity-driven research or engineering ambition, independent of funding policy or political considerations.
- Emerging from a realisation that progress in a particular field of science has reached a level of maturity that makes it possible to plan for widespread collaboration towards a goal that was previously impossible.

The following were Grand Challenges at time of writing:

- In Vivo–In Silico
- Ubiquitous Computing: Experience, Design and Science
- Memories for Life
- The Architecture of Brain and Mind
- Dependable Systems Evolution
- Journeys in Nonclassical Computation
- Learning for Life
- Bringing the Past to Life for the Citizen

But it is acknowledged that the current Grand Challenge proposals do not exhaust the possibilities, and the steering committee is interested in further ideas to be mounted on the Grand Challenges website to attract support.

More information can be found on UKCRC website: http://www.ukcrc.org.uk/grand_challenges/index.cfm

Oppositions

The following section of this report presents the meeting's thinking about the future. It is organised around oppositions, each with a concluding line of mission. This form reflects something of the nature and range of the discussions, capturing the many tensions inherent in computer science as a design discipline. It also acknowledges the view that prediction would be a meaningless activity. Instead, from these portraits emerge the values and states that were considered desirable.

Though the group only began to explore the tensions in these oppositions, it was felt that an appropriate future for computing would, in some way, respond to these concerns and resolve some of the tensions, or at least make assumptions more explicit.

Formalisation and richness

The tension between formalisation and richness came up in two contexts. The first was in describing the contribution that computer science makes to understanding the world. The second was in the context of introducing computers into people's activities.

The field of computing research called 'formal methods' captures one end of the spectrum between unclassified and therefore apparently chaotic life and the systematic approaches to organisation that allow for a particular form of scientific understanding. This process of computational thinking can be applied to anything from biochemical systems (see Muffy Calder's talk), to the behaviour of users when faced with a new gadget, to requirements gathering for software engineering. In this respect it spans the three generic areas of research raised at the meeting, while hailing from the core of 'pure' computer science.

Formalising can be seen as the process of tidying up, systematising, generalising and abstracting. It allows for the recognition of repeatability. It strips out detail deemed irrelevant in a situation, having focused on a particular question and the kind of modelling that might help to answer it. Even the models created by working this way can be evaluated using the same essential processes.

One benefit of formalising, it was stressed, is that the patterns such analysis reveals allow for prediction: they contribute to society's potential to do design in a range of fields from medicine to economics. At its most sophisticated, abstraction allows for the stochastic tendencies of complex scientific problems, while the continuing increases in performance make such undertakings manageable. In computing, patterns form the basis of the artificial worlds being created, organising binary code into algorithms. In natural science, as Calder points out, the activity of modelling is 'reverse engineering' rather than design. Both lead to new kinds of knowledge that can be applied across the board.

In social sciences, there is also some behaviour tractable to this kind of modelling. Embedded in system design based on formal methods tends to be a simplified or partial view of people and their behaviour, usually from the perspective of user and use, drawn from a model designed to define and represent relevant issues to the system's developers. Because fashions and priorities change and because people are culturally varied, modelling has its limits as a way of presenting guidance to designers of software in a way that does not affect natural sciences to the same extent.

This issue was highlighted more generally by Susan Leigh Star's discussion of orphans for infrastructure: any system creates a separation between the elements that are regarded as central to its function and those that are seen as atypical. The tidying up activities of formal methods bring a loss—sometimes at a theoretical level (as when one way of viewing a problem obscures another) and sometimes at a quite specific and practical level (as when someone who isn't modelled finds they can't use the chosen design—airbags were discussed here in the context of their danger to small/women drivers).

This cost was recognised and, consequently, in embracing the act of formalisation, the group attached a caveat: formalising has implicit within it a selection and rejection process. The process of defining and stripping down results in a loss of value as well as a gain. Therefore, it is important to recognise what has been excluded and explore alternative configurations, especially in the social area.

This tension between formalisation and richness has underpinned many discussions between scientists and social scientists (see, for instance, arguments around ethnography). Where it plays out more dramatically in the context of discussing visions is in watching the formal nature of computers confronting the rich nature of life.

Thus, formal methods may collectively be a useful research tool to make predictions and inform design, but they are also an intrinsic quality of how computers behave—machines need formalisation to work. This means that the increasing use of computers has the potential to push society more generally—and those that legislate and design for it—towards experiencing the world in formal terms.

This shift is not the same as a move to increase computational thinking by individuals. Instead, it is to speculate on the effect of the increasing mediation of human activities by logical systems that only process tidy data. Valuing computerisation and the control it offers may mean valuing the formal aspects of identity and social systems at the expense of the outlying, naughty, anomalous, chaotic, funny, deviant, qualitative and varied experiences of human life.

Vision: the future should be messy.

Centralisation and autonomy

A related opposition was that of centralisation and autonomy. Computers allow information to be transmitted, pooled and mined, which makes centralising knowledge considerably easier and more valuable. These same mechanisms enable customisation, in the shape of preference storage, niche marketing, just-in-time manufacturing and so on. So centralisation supports variety, but often results in standardisation of content as well as form. It can be the means to turn knowledge into a commodity, which has implications for areas such as education.

This limited approach was attributed in part to the limited grasp that people have of what technology can facilitate and what to demand from the designs they are implementing. As an antidote, what was needed was resilience: fitness for purpose and dependability. And centralisation, and the standardisation which may accompany it, should be a tool used to ensure access, not control. Resultant applications should be empowering and inclusive.

A fear was raised that morality has been delegated with the advent of technologies that preside over social issues and that we are letting sociotechnical systems make ethical and policy decisions on our behalf. Here, the suggestion was that systems should be designed for change, with the expectation that society was not going to stand still and that the ethics of one period would need changing for that of another. There should be built-in humility. For instance, if people find themselves depending on chips to prove identity (a position that already largely exists in the financial arena of industrialised countries), what is the fall-back position when the technology fails? Is the chipless individual a person or a non-person by default? The humble position is the one that allows the person the benefit of the doubt.

Vision: The future should be flexible. It should be varied.

Visibility and invisibility

Mentioned in many contexts was the matter of visibility. This was mostly addressed as quite a simple concept:

- that pure computer science should not be rendered invisible by the more public version of gadgets and applications that is understood as the discipline;
- that computer science as a whole should not disappear from view as computers become more absorbed in other functions;
- that credit should be forthcoming where academia had played a role, even if the implementation is visible only as an industrial activity;
- that interdisciplinary work should attract as much reward as other areas, rather than damage promotional prospects through poor showing for the British Research Assessment Exercise (RAE), for getting fellowships, etc. (see Box 2).
- that women should be increasingly visible in computer science as necessary and creative beings, regardless of how the future materialises in other respects.

However, the opposition of visibility and invisibility came into its own in the context of the ethics of pervasive computing. Should the function of computers become invisible as computers do? There was no simple answer. This, in part, reflects the fact that no one could talk about the future of ubiquitous computing with certainty. But more particularly it showed a concern that, while some functions may remain ambient and need not be articulated to users of the system, others need to be managed by the user, and yet further functions need only be understood at times when they malfunction, when such knowledge becomes essential.

It was felt that some visibility must be provided to keep an appropriate power relationship: humans should remain sovereign over machines; ordinary people should have some say in how their data is transmitted, pooled and mined. And this suggested that some education is needed to ensure that people can grasp the potential impact of design decisions (such as the effect of combining two sources of data and deducing from them—either correctly, or incorrectly—a third, more interesting and usable piece of information about what is going on). Visibility should extend to the implications, if not the guts, of applications and sometimes both would be in order.

Vision: the future should be feasible. It should be slower.

Box 2: Britain's Research Assessment Exercise

The Research Assessment Exercise controls how research funding is apportioned between Higher Education Institutions (HEIs) in the UK and is conducted jointly by the Higher Education Funding Council for England, the Scottish Funding Council, the Higher Education Funding Council for Wales and the Department for Employment and Learning, Northern Ireland. It was established in 1986 and the next exercise takes place in 2008 with submissions due late this year, to affect institutions' funding from 2009-10. After this, it is expected a new form of assessment based on departmental metrics will replace this more individualised means of carving up government support.

The RAE was introduced as a way of creating an explicit and formalised assessment process of the quality of research in UK higher education establishments. Exercises held in 1989, 1992 and 1996 became gradually more transparent, comprehensive and systematic, until the one in 2001 brought with it new and rigorous criteria, considering the work of almost 50,000 researchers in 2,598 submissions from 173 HEIs. Based on the prominence and impact of publications and on individual researcher's indicators of esteem, it is a system based on peer review with highly formalised criteria for evaluating submissions.

In the RAE 2008, each academic discipline is assigned to one of 67 units of assessment. Work submitted to the exercise is assessed by members of a panel corresponding to these 67 units, drawn for their expertise from HEIs and the wider research community, and nominated by subject associations and other stakeholder organisations.

More information can be found on the RAE website: http://www.rae.ac.uk/

Directability and unknowability

The need to make implications visible fed into another opposition that informed the discussions: that of the degree to which it is possible to know what you are developing when you develop computing applications.

The movements for social responsibility in computer science (see Box 3) stand in contrast to the pursuit of knowledge for its own sake that many academics sign up to. There is a strong will to work for the good of society and create systems that will lead to its betterment, though sometimes this is expressed without any articulation of the value system that determines what the right kind of betterment would be. Often, when articulated, there is a belief that it is not the job of computer scientists alone to decide the nature of society and that other groups should have some understanding of the ramifications of decisions, and a degree of input into how technology is implemented. The meeting felt that developments in computing should be accountable to a wide public.

Acknowledging that technological decisions have social consequences and vice versa, it would be desirable to make the relationship more defined so that it is easier to share, learn from and use as guidance. The complicating factor is that history repeatedly shows how wrong predictions of impact can be. Whether a technology is used and how it is used, when it will find a role and what it will displace are all matters that hinge on unknown social developments. So it is possible to drive certain fields of research and promise particular achievements successfully and still find that the uses to which the outcomes are put share nothing with the developers' agenda. When serendipity is involved, such as the exploitation of an engineer's backchannel that became SMS, no one can meaningfully discuss implications before inception.

Not least, there is sometimes a long gap between the founding technology and the application that takes it into society. The Web was a thirty-year overnight sensation, building on internet research conducted in the 1960s. The laser, discussed as a classic example of a tool waiting for its function, was a technology of the 1940s that no one could see a use for, except maybe as a weapon. Its value to everything from eye surgery to printers was not anticipated. Thus another relevant issue is the change in values and behaviour that sometimes occurs between generations, exemplified at present by young people's embracing of social networking tools and their willingness to share personal details in publicly accessible places. Privacy is a different matter to these people than it was to their parents. These people may prioritise different kinds of use and find different technologies useful. Nonetheless, issues such as those of identity and security can be raised to good effect, so that choices are made knowingly.

Big movements, such as the Grand Challenges, may be above this local churn, or may be just as much its victim. The conclusion was that it is possible to suggest what technologies are likely to be developed by looking at current trends and opportunities, but not what will become of them. Therefore, it is important to resist the narrow channelling of resources into solving only today's problems, and important to involve as many people as possible in speculating on the digital future of society.

Vision: the future should be fun(ded).

Box 3: Movements for social responsibility in computer science

The principal organisation in computer science that concerns itself with ethics and social responsibility is Computer Professionals for Social Responsibility (CPSR), organiser of many campaigns, events and conference series including the biennial Participatory Design Conference, and DIAC, Directions and Implications in Advanced Computing.

CPSR is a global organisation promoting the responsible use of computer technology. Incorporated in 1983, its brief is to educate policymakers and the public on a wide range of issues and it has incubated numerous projects such as Privaterra, the Public Sphere Project, EPIC (the Electronic Privacy Information Center), the 21st Century Project, and the Civil Society Project. Originally founded by US computer scientists, CPSR now has members in 26 countries on six continents.

CPSR is concerned about the impact of information and communications technology on society. Members engage both as experts on ICT issues and as concerned citizens, embracing five principles:

(1) to foster and support public discussion of, and public responsibility for decisions involving the use of technology in systems critical to society.

(2) to work to dispel popular myths about the infallibility of technologies.

(3) to challenge the assumption that technology alone can solve political and social problems.

(4) to examine critically social and technical issues within the information technology profession, both nationally and internationally.

(5) to encourage the use of information technology to improve quality of life.

More information can be found on the CPSR website: http://www.cpsr.org/

Orphans

Inevitably, some observations and concerns did not fit the classification system used above, which arranged issues as a series of oppositions. Here, then, are the orphans…

- Pure maths does no harm.
- I'd like a Babelfish that communicated what was meant by anything that's said. Even better if it could do it for animals.
- Running a computer is likely to be more expensive than buying one soon. Perhaps the hardware will be given away and cycles bought like other utilities.
- Assume that people are going to be negligent with their own data and design out crime, just as car manufacturers did by changing the shape of car locks.
- Women retire earlier than men, which is another reason that there are fewer women working in computer science disciplines. It isn't just about how many come in.
- I'd like a Slowdown machine that would help calculate when I'd exceeded my capacity and had algorithms for resting, appreciating, opting out, etc.
- Computer science has an image problem even within the discipline itself. I'd rather be identified as AI than as CS.

Pragmatic issues

As well as a wish list that looked at conceptual issues in computer research, there were practical matters identified that had a bearing on the future of the discipline in economic and motivational terms.

Some time was devoted to considering how to recruit students. Students mean revenue, so they are critical to a department's success. The appearance of bad computer science lessons in schools, unimaginative uses of ICT across the curriculum and the perception that jobs were no longer easy to come by in the wake of the dotcom crash has hit the number of applications to computer science courses. One suggested way round this was to market courses as something else and introduce large components of computing as part of it (for instance, games design, film technology, multimedia and graphics, etc). Another was to attempt to present computer science in a better light to 15-year-olds. What would attract 15-year-old girls? The gender imbalance is worsening, if anything.

Also considered was the quality of teaching in the computer science curriculum within universities. The research agenda dominates, so it is possible for practice in the lecture room to go stale without anyone noticing. How can drop-out be tackled? (See the previous

OII report: Rocket science or social science? Involving women in the creation of computing).[7]

Another concern was the state of academia more generally and keeping motivated. It was agreed that the job had become less attractive. An emphasis on winning funding, following fashionable trajectories and the (outgoing) RAE was removing some of the flexibility and creativity that had been associated with all fields of computer science during its relatively short history. If the rewards were less apparent to professors, there were other challenges in the ranks, like the plight of post-docs. Good researchers need cultivating.

In terms of progressing, the importance of access to the informal decision-making networks was stressed. Feedback from outside your institution to your peers and managers could be useful. And the need for tools of self-development was discussed. Human support might include mentors, sponsors, advocates (who mention you when you aren't there) and coaches (a paid role that can be useful in motivational terms and in organising career progression).

Participants

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Susan Craw	The Robert Gordon University, Aberdeen
Susan Eisenbach	Imperial College London
Beth Hutchison	IBM / Visiting Professor at University of York
Marina Jirotka	University of Oxford
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Gillian Lovegrove	BCS

[7] Martin, U., Liff, S., Dutton, W.H. and Light, A. (2004) Rocket science or social science? Involving women in the creation of computing. OII Forum Discussion Paper No. 3. Available at: http://www.oii.ox.ac.uk/resources/publications/FD3.pdf

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Jan Peters	Consultant/ BCS Forum on Women
Eileen Scanlon	Open University, Milton Keynes
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Speakers

Muffy Calder is Professor of Computing Science and currently Head of the Department of Computing Science at University of Glasgow. She is a member of the Scottish Science Advisory Committee, reporting to the Scottish Executive. Her research is in modelling and reasoning about the behaviour of complex software and biochemical systems using computer science, mathematics and automated reasoning tools. Her main research interests are in concurrent systems, process algebras and model checking. Recently she has become involved in computational biology, working with researchers from cardiovascular medicine and Cancer Research UK. She has long-standing industrial collaborations with many world-leading IT companies and in the distant past has been a research fellow at BT Laboratories and DEC in California. She has a PhD in Computational Science from the University of St Andrews and a BSc in Computing Science from the University of Stirling.

Margaret Martonosi is Professor of Electrical Engineering at Princeton University, where she has been on the faculty since 1994. She is also an Associate Dean for Princeton's School of Engineering and Applied Science and she holds an affiliated faculty appointment in Princeton CS. Martonosi's research interests are in computer architecture and the hardware/software interface, with particular focus on power-efficient systems and mobile computing. In the field of processor architecture, she has done extensive work on power modeling and management and on memory hierarchy performance and energy. In the field of mobile computing and sensor networks, Martonosi leads the Princeton ZebraNet project employing mobile ad hoc networking for wildlife tracking. Martonosi is co-author on over 90 refereed publications and inventor on five granted US patents. She completed her PhD at Stanford University, and also holds a Master's degree from Stanford and a bachelor's degree from Cornell University, all in Electrical Engineering.

Susan Leigh Star is Professor of Women and Gender Studies, and Senior Scholar at Santa Clara University, California. She is also President of the Society for the Social Study of Science (4S). She was among the first ethnographers to work closely with computer scientists, and has been a part of many development projects. She writes theory about the information society, particularly gender, technology, and information science itself. With Geoffrey Bowker, she is the author of Sorting Things Out: Classification and Its Consequences (MIT Press, 1999), a classic cross-disciplinary study of how categories are made and used.