Technology & Standards Watch
www.jisc.ac.uk/techwatch

Will we be able to cope with the invisible computer?

By Paul Anderson

JISC Technology and Standards Watch report on **The Computer Journal Lecture** for the British Computer Society: *Ubiquitous computing: shall we understand it?* Presented by Professor Robin Milner, University of Cambridge, 23rd February 2006.

Nearly twenty years ago Mark Weiser of Xerox PARC outlined a new, monumental vision for computing, one in which the computer disappears from view and becomes pervasive, embedded into our urban environments, our clothes and even our bodies (Weiser, 1991). Mark Weiser died before his dream of a 'calm technology', melting into the background of our lives, could be realised but his vision - ubiquitous computing - has become one of the guiding aspirations of the computing community and has opened up a new frontier for research.

In the ubiquitous computing (ubicomp) world a multitude of computationally capable, small - sometimes invisible - devices will be scattered throughout our environments, operating silently and largely unseen as they go about their individual tasks to support our daily activities. In a step-change that will be orders of magnitude greater when compared to today's computers, a bewildering population of heterogeneous sensors, computers and actuators will be operating. Often, these devices will operate with self-awareness (being 'conscious' for example, of their physical location and their immediate surroundings) and be widely networked together – perhaps even acting as a kind of single entity: the Global Ubiquitous Computer (GUC).

The scale and complexity of the technology involved in ubicomp raises a fundamental question: will we be able to understand it? It is certainly a question exercising Professor Robin Milner, the noted Cambridge computer theoretician (Milner, 2006). Ubicomp has become one of the Grand Challenges of computer science that are being overseen by the UK Computing Research Committee (UKCRC). These challenges represent key goals in computer science that will take a decade or two of co-ordinated research to realise (Hoare and Milner, 2005), and achieving these goals will represent the achievement of major scientific and cultural milestones. There are currently six Grand Challenges and the ubicomp challenge is known as Ubiquitous Computing: Experience, Design and Science (UbicompGC) (Chalmers et al., 2006). The UbicompGC proposes to tackle three essential, closely coupled, problem perspectives: the novel human and social experiences of using these new systems (*experience*), the development of a set of robust engineering design principles that will allow us to successfully build such systems (*design*) and the development of theoretical science foundations to underpin the other two (the production of theories, models, logic, programming languages etc.) (*science*).

And this Challenge is hard. Likening the development of ubicomp as ‘climbing up the most enormous and varied mountain range’, Milner outlined the unprecedented level of difficulty in dealing with systems that are orders of magnitude more complex than today’s systems. In fact, there are those that take the pessimistic view that the complexity is too great. The response to this difficulty is to look at what initial, incremental steps might move the problem forward and in his lecture Prof. Milner made clear his view of the essential nature of the third of these perspectives (theoretical science) in the role of developing successful and understandable ubicomp systems.

There are two clear reasons to focus attention on the theoretical or software science perspective of the problem. Firstly, current, conventional computing (the second wave) has not paid as much attention to the actual science of computing and the associated fundamental theory as it arguably should have. A lot of conceptual work has been done that is robust and well worked out but in Milner’s view this has not transferred to the engineering and technology world where ‘the impact on practice has actually been low and haphazard’. This is in part because of the dizzying speed of technological innovation and the continual demands of the market. His key argument is that in the highly complex new world of third wave (ubicomp) computing, if we are going to be able to understand and develop systems that work correctly and function in a safe and trusted manner then it is essential that we take a more scientific approach. Secondly, the development of a more robust theory, ‘the essential organising principles of our science’, will help computer science itself become more embedded into the scientific culture, as we see in other science disciplines.

How might we go about the development of the models and theories required to underpin ubicomp? Such models will need to be rigorous and capture the behaviour of ubicomp systems at varying levels of abstraction. Even a cursory review of the complexities involved in ubicomp systems reveals a tangle of concepts. Milner’s vision is of the piecemeal development of a tower of models, each level operating at a different level of abstraction. Lower level, and hence perhaps more understandable, models can be used to realise higher-level models (see the forthcoming paper for details).

The first steps in solving the ubicomp Grand Challenge are to embark on a series of exploratory projects, which will help define the overall essence of the ubicomp vision. These will evolve into a series of foothill projects, which will help to synthesise the results of these explorations and feed into the development of a future roadmap for the challenge. These foothill projects should be relatively short (two or three years), involve a small number of ubicomp concepts and cross at least two of the three problem perspectives (human experience, design or science). To date, there are six foothill topics, including the analysis of movement in a sentient environment, ubiquitous healthcare and automating the highway (traffic flows).

Can we meet the Challenge? Will computing be able to handle the complexity of a ubiquitous world? Nobody knows. In a sense that is one of the key roles of a grand challenge. It is as much about the journey up the mountains as the view from the top. Professor Milner argues that, since at the end of the day the systems are to be built by us, then we can and should understand them. But we really will need to pay a bit more attention to theoreticians this time as we edge up the slopes.

TSW Comment

What relevance does this have to the long-term development of tertiary education? The six Grand Challenges offer great opportunities for the research community from across many disciplines within tertiary education. The first Challenge (*In Vivo-in Silico*), to take one example, has the goal of developing computer embodiments, through simulation, of living systems and it presents considerable opportunities for computing and the life sciences to work together.

As far as the ubicomp Challenge, specifically, is concerned, it is obvious that education is a facet of human society and will be affected by a general move to the ubicomp vision as much as any other avenue of life. But even more specifically, how might the way that we learn change as the nature of computing and information society changes? Increasingly, teachers are looking to move some aspects of education beyond a class and lecture setting and this is being facilitated by mobile computing – but what will happen when this is normal practice? When computing power and very large-scale memory is ubiquitously available will this change the way we define educational competencies? Education is a human-centred endeavour and so there should be particular scope for educationalists to be involved with the experience perspective of the Grand Challenge. Some of the early exploratory experiments have included developing experiences of ubicomp in learning environments (see, for example, the Equator project's section on playing and learning: http://www.equator.ac.uk/index.php/articles/c64), but the existing six foothill projects do not have a specific focus on learning environments. The committee is looking for suggestions for further foothill projects–perhaps someone in HE/FE has some ideas?

References

CHALMERS, D., CHALMERS, M., CROWCROFT, J., KWIATKOWSKA, M., MILNER, R. et al. 2006. *Manifesto for the Ubiquitous Computing Grand Challenge: Experience, Design and Science*. Version 4. **UK-UbiNet.** 23rd Feb 2006. Available online at: http://www-dse.doc.ic.ac.uk/Projects/UbiNet/GC/manifesto.html [last accessed 10/03/06].

HOARE, T., MILNER, R. 2005. *Grand Challenges for Computing Research.* **The Computer Journal**. Vol. 48, no. 1, pp. 49–52. The British Computer Society: London.

MILNER, R. 2006. *Ubiquitous computing: Shall we understand it?* With Discussion. The First Computer Journal Lecture, **The Computer Journal** (forthcoming).

WEISER, M. 1991. *The computer for the 21st century*. **Scientific American**, September 1991, pp. 94–104.