PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A

Phil. Trans. R. Soc. A (2008) **366**, 3665–3668
doi:10.1098/rsta.2008.0154
Published online 31 July 2008

Introduction

This issue contains papers from the Royal Society Discussion Meeting entitled 'From computers to ubiquitous computing, by 2020', which was held in the Royal Society in central London on 17 and 18 March 2008. It is a great honour to have served as the lead organizer for the Discussion Meeting and Guest Editor for this issue to appear in the world's oldest continuously published journal *Philosophical Transactions of the Royal Society A*.

The meeting contributed to the activities of the UK Computing Research Grand Challenge on *Ubiquitous Computing: Experience, Design and Science* (*UbicompGC*; http://www-dse.doc.ic.ac.uk/Projects/UbiNet/GC). It was designed to increase awareness of the challenge, its key scientific issues and benefits and risks to society, and was supported by the UbicompGC Steering Committee, which includes Prof. Morris Sloman, Imperial College London (Chair), Dr Dan Chalmers, University of Sussex, Prof. Jon Crowcroft, University of Cambridge, Prof. Robin Milner, University of Cambridge, Prof. Tom Rodden, University of Nottingham, Prof. Vladimiro Sassone, University of Southampton, and myself.

The UbicompGC initiative is a response to the momentous developments occurring in the world around us, which represent a shift from 'visible' to 'invisible' computing. The phenomenon is best known as 'ubiquitous computing', first identified as a trend by Marc Weiser in 1988, but is also referred to as pervasive computing. We are already witnessing a huge increase in the numbers of miniature computing devices—almost imperceptible, but often globally connected and everywhere around us—embedded in smart buildings, shops, vehicles, environment, clothing and even implanted in the human body. They are used to control processes, monitor the environment and our health, and communicate with others and other devices, in learning, fun, business and intellectual endeavour, at home or during travel. Our interaction with them is an extension of normal everyday activities. In the words of Adam Greenfield (Greenfield 2008), these items of technology (RFIDs, short-range wireless, sensors) are 'everyware' (Greenfield 2006), offering seemingly endless opportunities to spearhead technological innovation and commercial development.

Clearly, ubiquitous computing has enormous potential, but how well do we understand the full implications of its widespread adoption? Ambitious exploitation proposals are often met with concerns, from both ordinary citizens (Can I trust the mobile phone access to online banking service? Is the chemical pollution sensor reliable? How do I know that the on-body sensor is safe?) and system designers and developers (How best to coordinate a wireless network consisting of a multitude of devices? What theories can help in ensuring

One contribution of 19 to a Discussion Meeting Issue 'From computers to ubiquitous computing, by 2020'.

fast and secure access to private electronic data? What are effective ways of communicating with miniature sensors?). The UbicompGC initiative is addressing those concerns through a three-angled approach: experience, focused on how best to embed everyware in the fabric of everyday life; design, focused on engineering design principles; and science, focused on how to understand and analyse such systems. By 2020, we anticipate that much progress will have been made in those areas.

The Discussion Meeting was interdisciplinary and aimed to give a broad overview of pertinent technological, scientific and societal issues in ubiquitous computing. The speakers were chosen not only to highlight opportunities of the technologies but also to draw attention to potential risks, thus engaging the wider community in topical discussions. The lectures were grouped thematically and began with a discussion of the existing technologies and examples of their uses: a report on an experiment in invisible computing by Prof. Borriello (Borriello 2008); the energy usage implications of a global sensing infrastructure put forward by Prof. Hopper (Hopper & Rice 2008); an exemplar of a sparse mobile network architecture, not only for the monitoring of animal populations but also of relevance to urban environments, by Prof. Martonosi (Hari *et al.* 2008); and network architecture for large-scale computing by Prof. Roscoe (Roscoe 2008). Next, the focus has shifted to the underpinning science for ubiquitous computing, and especially the role of computer science within it: Prof. Wing (Wing 2008) advocated her view of 'computational thinking' influencing future human endeavour in a major way, calling for computing to enter the mainstream education; Prof. Henzinger (Henzinger 2008) identified two main scientific challenges in embedded systems design—predictability and robustness—and argued the need for appropriate theories; Prof. De Nicola (De Nicola & Loreti 2008) presented conceptual and implementation issues for global computing; and Prof. Babaoglu (Babaoglu & Jelasity 2008) discussed the role of self-$*$ properties of large-scale complex systems. The following three lectures pertained to privacy and trust assurance technologies: Prof. Rivest (Rivest 2008) considered requirements for electronic voting; Prof. Joshi (Joshi *et al.* 2008) described the role of security policies; and Prof. Nielsen (Krukow *et al.* 2008) stressed the need for formal models for trust technologies. Next, Prof. Marsden (Marsden *et al.* 2008) gave a fascinating insight into the role that mobile phones can play in the developing world, and how this has, in turn, influenced the interaction design methodology; and Prof. Darzi (Aziz *et al.* 2008) presented his vision of pervasive health care technology, describing medical applications of wireless body sensor networks and the trend towards personalized health care, to be achieved by 2010. The last two lectures concerned legal and ethical implications of ubiquitous computing: Prof. Zittrain (Zittrain 2008) pinpointed the dangers of unregulated 'human ubiquitous computing' that combines the power of the Internet and humans to perform tasks; and in the final lecture Adam Greenfield (Greenfield 2008) enunciated five principles of ethical development of ubiquitous computing.

The meeting was attended by 200 participants from a variety of backgrounds, representing a cross section of current and future researchers, technologists and education experts. The often palpable excitement about their work conveyed by the speakers was met with a tremendous response from the audience. There was vigorous discussion throughout the meeting, which culminated in the panel

discussion chaired by Prof. Wendy Hall held during the last session. The panellists were chosen to represent the three angles on ubiquitous computing—experience, design and science—identified in the UbicompGC Grand Challenge. The three panellists, Prof. Jon Crowcroft (Crowcroft 2008), Prof. Robin Milner (Milner 2008) and Prof. Tom Rodden (Rodden 2008), are key contributors to the UbicompGC manifesto and their respective position papers are included in this issue. The questions posed throughout the meeting were wide ranging, not only reflecting a genuine interest in the concepts and ideas presented, but also raising deep philosophical issues about ubiquitous computing and the need for ethical boundaries to be imposed. The atmosphere in this uniquely broad gathering was one of scientific curiosity and excitement at the prospects of ubiquitous computing, and also of awareness of potential pitfalls due to naive or poorly thought-out solutions.

It is thus with great pleasure that I present to you the collection of the invited papers from the Discussion Meeting. I hope that it will serve its purpose to introduce to you this exciting field, its future challenges and fruitful directions, and also inspire new avenues and colleagues to join this interdisciplinary initiative.

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