Chapter 14
Navigating a Speckled World:
Interacting with Wireless Sensor Networks

Matthew Leach
Napier University, UK

David Benyon
Napier University, UK

ABSTRACT

The Speckled Computing project is a large multisite research project based in Scotland, UK. The aim of the project is to investigate, prototype, and produce tiny (1mm³) computational devices, called Specks, that can be configured into wireless sensor networks, called SpeckNets. Our particular interest is in how people might interact in such environments, what interaction tools they require, and what characteristics are required to be provided by the operating system of the Specks. Interaction in these environments places the human physically inside an information space. At one time, the human may be interacting with one Speck, at another with a hundred, and at another with several thousand. Moreover, the Specks themselves have no input method, apart from their sensors, and no output display. We explore these issues through taking some theories of distributed information spaces, some design principles from information visualization, and report on some empirical studies of prototypes and simulations that have been developed.

INTRODUCTION

We are interested in human interaction with a new type of information space, one that involves computer miniaturisation, sensors, wireless communication, and networking. Devices are on the verge of reaching a critical point of size and affordability that will allow them to be embedded in our environment in their thousands, sensing their surroundings and opening up a broad range of new applications. They will also be embedded in clothing and jewellery, truly becoming part of the fabric of the world. It is a vision that was foreseen by Mark Weiser (2002), who coined the term "ubiquitous computing"; but it is likely that even he would be astounded at the miniaturisation of technology that has made his prediction possible, in projects such as SmartDust (Hoffman, 2003), and more recently the Speckled Computing Consortium (2006).

The vision of Speckled Computing is the development of miniature 1mm^3 computational devices (Specks), which will be simple, small, and cheap enough to be distributed in their thousands (Arvind, 2005). They will combine wirelessly to form a unique class of wireless sensor networks (WSN), called SpeckNets. Some SpeckNets will be embedded in the fabric of buildings, but others will be spontaneously created by scattering Specks over an area or even spraying them onto surfaces. The combined storage and processing of the microchip revolutionised computing in the late 20th century. Specks, offering combined processing, storage, sensing, and communications, are expected to revolutionise computing in the 21st.

The characteristics of SpeckNets give rise to some specific requirements for human-SpeckNet interaction. First, the invisibility of the Specks and the lack of any perceptible output mechanism means the human-Speck interface must be provided through some other mechanism. Second, people may literally be immersed in the network surrounded by Specks, of various types in various configurations, in three dimensions; they are not interacting with a device, they are inside an information space. Third, the SpeckNet may not know about the physical characteristics of the real world. In stable SpeckNets, it would be possible for the network to develop a model of the world and relate this to its own configuration. However, in recently created or in movable SpeckNets, the human will have to supply information about the physical world. Finally, there is the issue of scaling interaction from individual Specks to potentially thousands.

Previous work on WSNs and human interaction with these networks identifies a number of different types, depending on the method of deployment of the nodes, their size, the communication mechanism, and the network's topology (Romer & Mattern, 2004). There have been many WSN applications, each with its own interaction methods and techniques. For example, a sensor network has been embedded within a vineyard. The system would automatically trigger an event, such as turning on sprinklers when soil moisture is low or firing air cannons when birds were detected (Burrell, Broke, & Beckwith, 2004). Another example is the self-healing minefield (SHM), a minefield that can reorganise itself (through mobile mines) to cover gaps that appear (Meriall, Newberg, Sohrabi, Kaiser, & Pottie, 2003). ARGO is a global network with an intended 3,000 sensors that will monitor salinity, temperature, fresh water storage, and so forth, of the upper layers of the oceans, and transmit results via satellite. Deployment began in 2000, and as of February 2006, 2,385 floats were in operation (Argo Project Office, 2006). In most of these applications, data was sent from the network to a remote database.

In contrast, we are interested in WSNs where the person is inside and interacting with the network directly; SpeckNets. We describe a generic tool-kit for humans interacting with SpeckNets, focusing specifically on the unique characteristics that separate them from other WSNs. In the next section, we elaborate on the requirements that this interaction demands. This is followed by some background theories that have helped to shape the tools. Some studies of alternative designs are described that help to evaluate the effectiveness of both theory and tools. The chapter closes with some conclusions and indications concerning the future of interaction in WSNs.