

## Do we need to revise the Equator vision?

### *A draft discussion document*

The Equator IRC finds itself at an interesting point in its lifetime. If this were a “normal” 3 year EPSRC grant we would now be considering how to complete the current set of work and what our next sequence of proposal and projects might be. However, the six-year lifetime of an IRC allows us to focus not on our next projects but what are the next steps for the body of work we have already established and how this body of work relates to the original vision outlined within our proposal.

This document aims to provide a starting point for discussion and offers positions that need to be developed and refined. I wish to briefly reconsider the equator vision, recap on the work to date and to reflect on the challenges we may now tackle over the remainder of the lifetime of the IRC. I believe it is important that we focus on the research topics that Equator is uniquely placed to tackle and how we may organise our forthcoming activities in order to allow us to focus our work on areas where we can make the greatest contribution to the state of the art. In many ways this represents the point where the activities of the Equator as an IRC become distinguished from those of a collection of equivalent EPSRC research projects. We are in the very fortunate position of having the main thrust of our research work supported for at least six years and we should exploit the opportunity this level of support provides for us.

### The Initial Equator Vision

The original introduction to the outline equator proposal serves as the earliest and perhaps most succinct statement of the overall vision of equator.

“The Equator IRC will develop new ways of interacting with digital information that are in harmony with everyday life, focusing on the boundary between the physical and digital aspects of our lives. It brings together researchers from different traditions who are expert in the design, development and effects of interactive technology.

*Equator’s central mission is to develop systems, applications, and understandings that promote the synthesis of our physical environment and digital space, thereby improving the quality of life in a culture that has information and communication technology at its heart.*

The deployment of a world wide distributed infrastructure has seen the emergence of the Internet as a vibrant digital resource shared by an ever-expanding community of users. Twenty years ago, distributed digital information was restricted to research workers; most people were either excluded or oblivious. Today millions have their own pages on the World Wide Web, and many routinely use on-line services. With the development of mobile communication facilities, on-line access from anywhere for everyone is seen as imminent and inevitable rather than a fanciful speculation. An ever more reliable and higher bandwidth digital infrastructure interconnects an increasingly heterogeneous collection of devices and services.

The convergence of interactive digital systems, local and wide area networks and mobile communications has already started to transform the ways that people entertain themselves, work, shop and converse. We increasingly undertake everyday activities and share our lives with others, both in our physical environment and in digital spaces. We continually step over the border between the two: many actions in our physical environment have counterparts and effects in digital space, and vice versa. It becomes possible to link geographically distant people, to access information from remote locations, and to draw from the recorded past to support ongoing activity and choices for the future. The day after an on-line purchase, a book drops heavily onto my doormat. A car driver checks her location, plan, and route recommendations on a dashboard display, circumventing a traffic jam while hardly aware of the system of computers and satellites in the background. A traveller swipes a card at an airport turnstile, unconcerned by the hidden flurry of checks and calculations that let him board his flight.

Despite the growing prominence of this new lifestyle, the boundary between physical environments and digital space is often over-complex and poorly designed. We too often take a narrow perspective, seeing interaction as information processing, and interaction technology as just the desktop computer. This leads to a focus on issues of effectiveness, efficiency, precision and fidelity of information. We need to broaden our view of interaction to consider the whole gamut of human activities, understanding how information systems are a medium of communication between people as much as a tool for the individual to access data. To allow the general citizen to exploit a universally accessible digital infrastructure, we must develop a seamless boundary between the physical and the digital. People should be able to pass between the two sides so easily that the boundary becomes just a line on a map, rather than a hurdle to their activities, goals and desires. The end result will be a universal mixed reality, a ubiquitous global environment that combines the physical and the digital on an equal footing. Creating such an environment requires long term research into new interface and distribution technologies, new applications and new methods. It also requires a shift in our thinking about interaction and design, towards theories, practices and techniques built on a multidisciplinary base of art, design, social science, HCI, interactive device design, and communication infrastructures.”

### **Reflecting on the initial Vision**

Essentially, this vision constructs a separation between *the Physical* and *the Digital* and outlines the core objective of Equator as providing the research needed to bridge between the physical and the digital. Although it offers a useful mechanism for articulating the need to address a broad set of concerns involving understanding and supporting interaction that is manifest both physically and digitally this separation has proven less useful in practice as a means of driving our research. In fact, a number of the discussions surrounding many of the understanding interaction challenges have directly raised problems associated with this separation and the issue of seamless and/or seamfullness has become a growing theme as we seek to deepen our understanding of interaction.

As it currently stands it is not clear which parts of the work of equator have directly tackled bridging between the physical and the digital allowing users to “step over the border between the two”. We have work that combines digital and physical interaction, we have work that carefully embeds digital devices and media into the physical world, both internally and externally and we have work that allows activities in the physical world to be manifest within virtual environments. Much of this work has gained international recognition and has brought together a wide range of disciplinary perspectives.

However, the question remains how to respond when the central tenet of the IRC’s original articulation of its vision is deemed to lack relevance at best and to be problematic at worst when it is used as a means of driving our research. Should we abandon our work to date? Do we need to correct the direction of our work? Should we reconsider the ways in which we present Equator and describe the work of the IRC? I believe we need to strategically reflect on our current position and to articulate some of the core challenges that remain for the Equator IRC over the coming four years.

### **Equator Work to date**

Over the last two years the work of the Equator IRC has made considerable progress and the IRC should feel some satisfaction with progress to date. Equator has developed a strong collegial culture, we have promoted inter site and inter disciplinary working, we have engaged with a number of user groups and we have started a number of distinctive equator experience projects. Many of these activities reflect that we are currently working as Interdisciplinary Research Collaboration. Work has followed the broad structure of the proposal workplan and has divided into Experience Projects and Research Challenges.

#### **The Experience projects**

A driving force of year one was the establishment of a set of experience projects that engaged with users and provided a means for different members of the IRC to work together. These different projects align the physical and the digital in different ways<sup>1</sup>

- **The city project** exploits the Makintosh collection as a physical setting for a range of devices. It considers how visiting may be understood from three distinct perspectives, the physical visitor, the web visitor and the visitor using a VR environment. It is worth noting that the dominance of the physical environment in this project even though this is the main project where an inhabited virtual environment is presented using VR techniques.
- **Citywide performance** considers city streets as a setting for “on the street” performances where contextual digital information is used as an integral part of the performance. Digital information is made available to players on the street through handheld devices. On-line players are presented with a map of the street although showing a virtual space this is done using a 2D interface. Again the focus of our research has tended to be on how digital information is placed into the hands of player and how their physical activities (mainly movement) can be tracked.
- **Snark to Park** has focused on providing a series of learning experiences for young children. This work has exploited a broad range of technologies to provide children with digitally rich environments. These environments are experienced physically and are supplemented with digital information and sensing of the physical movement of the children. There has tended to be less consideration of the development of digital environments for the children to understand and explore with the digital providing a basis for reflection after the event.
- **The domestic** has focused on understanding the physical setting of domestic environments and designing for these. This work has included studies of domestic environments and the use of technology in these environments, physical sensing of features within domestic environments (e.g weight) and the design of devices to be placed in these environments. There has tended to be less consideration on the development of a digital world in this area of work with the exception of proposed work on digital home health and the emerging work on configuring devices for the home.
- **Community care** has focused on supporting care workers within the sheltered housing set-up at Carlisle. The focus of this work has been on the provision of communication and coordination facilities that allow staff members to be aware of each other and the context of those within the Carlisle set-up. Again the focus has been on situating devices in everyday settings rather than the development of virtual environments.

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<sup>1</sup> These represent my view of these activities from the outset and are intended to provide the basis for discussion.

Indeed it could be argued from a initial investigation of the work of the projects to date that we have focused on how digital information becomes available within physical settings and how we sense the activities of people within these settings. Work on virtual environments has tended to be much narrower in focus (e.g the work on avatar gaze at UCL) and has tended not to be the principle organising principle within any of Equator's experience projects driving the first two years of the IRC.

### **The Research Challenges**

The second year of the IRC has seen a growing emphasis on research challenges with the initiation a set of research activities that seeks to exploit the portfolio of experience projects that emerged to date in order to tackle more fundamental research topics and challenges. These research challenges have reflected on the core Equator mission in slightly different ways and the activities have also progressed in different ways.

- **The understanding interaction** challenge has been addressed through a combination of specific workshops and the broader writers retreats. This has led to a number of distinct pieces of work
  - Senseable and Sensible, which considers the design of physical interaction
  - Ambiguity as a resource for Design, which considers how ambiguity can be used a basis for the design of interactive systems
  - The evolution of buildings, which consider how the framework suggested by brand may be applied to ubiquitous computing
  - Seamfulness and Seamlessness, which considers the different relationships between the physical and the digital

These areas of work outline new concepts and frameworks to help understand interaction and to support future designers. However, it is worth reflecting that the majority of these reflections have taken the embedding of digital technology within physical environments or the sensing of physical effects as their starting point. Few have considered the design of virtual environments.

- **The adaptive infrastructure challenge** has taken a very practical approach over the first two years. The focus of the work has been on the development and deployment of a pragmatic infrastructure to support the work of the projects and to help us gain experience. We have tended to focus on utility of infrastructure and the crafting combinations of different infrastructures. We have exploited virtual environment software here although this has tended to be less concerned with being presented as a virtual environment. We have also considered the development of wearable infrastructures and construction of hardware devices (through the involvement of Smart-It infrastructure). We have tended to focus on less exploratory and risky infrastructure work. This has gained us considerable experience in the development and deployment of infrastructures across a broad set of domains.
- **The devices challenge** like the adaptive infrastructure challenge has tended to undertake a pragmatic approach to its research offering support for a range of different practical experience projects. We have seen the development of position and location technologies, the construction of the weight table, the development of new wearable devices. It is worth noting that although the proposal and original vision made a separation between device challenges and adaptive infrastructure challenges that our work over the first two years of equator has not exploited this separation. If anything the work of Equator has blurred this boundary.

The second year of equator has seen a shift in emphasis toward tackling the fundamental long-term research challenges that underpin the work of the project. This work has tended to focus on the challenges surrounding understanding interaction with less emphasis placed on articulating the long-term research issues surrounding the infrastructures used to realise these environments. One of the most immediate reflections is that this strategy has allowed us to develop and deploy a wide variety of ubiquitous, pervasive and virtual environments. We are now well positioned to exploit these experiences to consider the long-term infrastructure challenges needed to support these environments. The next four years offers the opportunity to more directly tackle these fundamental infrastructure challenges in a manner that exploits the experiences we have already gained from our existing pragmatic approach. We also have the sufficient time to allow these fundamental infrastructures to mature to the point where they may be fed into experience projects.

### **Does our original vision match our work?**

Given the current potential mismatch between the original vision and our current work trajectory is it worth articulating a new vision for the IRC? It is not clear that we would want to hang the body of work undertaken during the first two years as focusing on bringing the physical and digital closer together. I would argue that our intuition has been to focus on the everyday physical environments and how digital information finds its way into this environment. For example, work in virtual environments has tended to be in support of this placement of digital technology or on reflecting sensed physical activities within these environments. It is not clear what we see a equal partnership between the physical and digital world (which could be implied from the existing articulation of the Equator vision). In seeking to articulate a revised vision for Equator it is worth reflecting on the unique features of us as an IRC and of the work currently being undertaken within Equator.

### **Particular features of the Equator IRC**

A number of particular features distinguish the Equator IRC from other endeavours. These are a feature of the funding model, the location and style of our research, our baseline of technologies and our working style. These include

- **Access to a broad set of advanced skills.** Our distributed nature means that the diversity and experience of researchers we have access to in equator is in advance of those that can be assembled at a single institution. We have established research teams in a broad set of concerns which means the scope of disciplines involved in our research can be more ambitious than for any single institutions.
- **Stability of long term funding.** We have guaranteed support for at least the next four years and can focus our research to reflect this long-term commitment. This gives us the opportunity to take a long-term perspective on our research and to adopt a style of research that capitalises on this funding.
- **Access to a diverse community of users.** We have established during the first two years of equator access to a broad set of users. This access means that it is possible to consider general issues that span these domains and to work with these users over a long time period.
- **Flexibility of mechanisms.** One of the most significant features of our working style is that we have considerable flexibility in the mechanisms we can use to tackle work this includes involving other researchers, supporting fellowships, focused workshops, project work, targeted development activities etc.

### **Particular features of the work of Equator**

Before we consider what a new vision for equator might mean and what its implications are for our future activities it is worth also reflecting on the key feature of the work undertaken within equator to date.

- **It extends digital technology beyond work.** We have taken as a key element of much of our activities extending our understanding of computers beyond the set of values normally associated with work and have sought to address values beyond work by considering education, entertainment and the domestic.
- **It is strongly multidisciplinary.** Our activities to date have sought to combine a broad set of disciplines in all aspects of our work and to benefit from bringing these disciplines together.
- **It is collaborative between institutions.** We have developed a strong ethos of cross-site working with many of our key activities reflecting the contributions of a number of different centres of expertise.
- **It engages with users.** Most of our work engages directly with real world users and seeks to exploit the lessons we have learned from this engagement with users.
- **It seeks to be internationally leading.** We have sought to focus our work on areas where we can be internationally leading and have developed publications that reflect a particular equator stance for submission to leading journals.
- **It has strong international links.** We have been fortunate in building upon our external links. We have activities planned with researchers in the US and have been involved in establishing research programmes in Sweden (Daphne) and in Australia (The CRC for digital physical interaction at UQ) that mirror the broad approach of equator and seek to collaborate with us.

As a final reflection it is worth stressing that a key feature of Equator is that researchers are enthusiastic about their particular research and much of our success is based on this enthusiasm. It is important that we encourage and support these researchers and that organising the programme of work around the interests of our research remains a key feature of how we plan our work.

### **Potential vulnerabilities of Equator**

Our current approach to equator has provided significant success in terms of our engagement with users, our understanding of interaction in this domain and the development of publications (e.g. 5 CHI papers from 8 Submissions, nearly all multi-site). However, it is worth reflecting on some of the vulnerabilities I feel that we may face.

- **We fail to make significant contribution to underlying technologies.** A potential danger we face is that Equator is seen as focusing on understanding users with less emphasis on the development and deployment of new technologies. This would misrepresent our work and we need to ensure that the technological advances inherent in our work.
- **We fail to demonstrate industrial relevance.** Although we have significant benefits from our research focus many of the benefits of the work could be overlooked by industry if we do not articulate these clearly enough. It is now timely to complement our academic research work with cooperation with more industrial interests to ensure that the benefits of our work are clearly articulated and to explicitly seek to make these links as part of our research work.
- **We lose our adventurous advantage.** One of the key strengths of Equator is the work is unequivocally adventurous in nature. Our funding and mix of disciplines have allowed us to deliberately explore issues and topics that are outside the scope of many researchers at the "centre" of existing disciplines and research areas. As we are successful in these activities and in articulating them then our distinctiveness will diminish. For example, consider the growth over the last three years in researchers exploring ubiquitous computing. It is important that we replenish the adventurous aspects of our research agenda.

- ***We are submerged by new initiatives.*** At the time of funding Equator was the largest research endeavour in the UK and we were expected to demonstrate the advantages of critical mass in gaining impact and recognition. Since then other initiatives such as eScience have emerged and Equator's activities may well get submerged in these endeavours. This is particularly pertinent given that Equator has a research projects in this domain and the document on future computing challenges for eScience (to be funded at the level of approx £20M) takes a particularly Equator based stance on the future of eScience. The text of this document is available from <http://umbriel.dcs.gla.ac.uk/NeSC/general/news/Vision.pdf>

## Implications for our future work

What does any realignment of the Equator vision say about our future work plan? This has to be debated across the project. It is clear from our experiences to date that researchers who feel they own the research and wish to tackle the research drive our most successful work. There is very little to be gained by constructing potential areas of work that does not enthuse people within Equator. If we do so we potentially reduce the amount of energy within the IRC. We need to map the potential we have to tackle the issues we have addressed with the skills and enthusiasms of those in the research teams. We already have a number of suggestions for future areas of work that we may want to match to this bigger vision.

However, there are some areas of activity that I feel we need to make sure we focus on in the coming months. These include the issues already raised by Steve Benford during our email debate.

1. **Adaptive infrastructure.** I do think that we need to take this on as a matter of urgency and thanks to Adrian for his suggestions and also to various people for previous issues documents. However, I think that there is another key issue that we need to address - the relationship between hardware and software infrastructures. With the introduction of the Smart ITs into Equator we are in a potentially very strong position to take this on. We now have a hardware prototyping platform and a range of software platforms (Equip, Elvin ...). If we could produce an integrated toolkit spanning these, then we would really have achieved something. The question is how to go ahead. What kinds of project mechanisms do we need - workshops, integration fests? What will the results be of this - publications, toolkits for others to use?
2. **Outreach** I feel very strongly that we need to put more effort into being more outward facing. This means higher profile in the academic community and also better industrial links. Key activities here are: - completely revise and improve our website - promotional activities - especially in the US - develop and formalise international links - introduce some kind of an industry club mechanism - push our research through into teaching through summer schools and online resources I have a sabbatical beginning in June 2003 for a year and would like to spend some of my time pushing these activities. It would need some additional budget, e.g., for travel and hiring writers and graphic designers.
3. **e-science** We do need to fold these two new projects into Equator proper over the next year. They have two implications. First, they at least partially address the theme of 'work' from the original proposal. Second, given that we are already getting two new projects up and running, I think that this gives us quite a lot of time to think about any other new projects that might come along. We need to make sure that the new e-science projects are present on the web site, in project materials and fully represented at future meetings.
4. **Equator specific foci** We need to be clear about what is distinctive about Equator's work. Some of our distinctives are:
  - a. a focus on designing complex experiences that knit together collections of devices and environments (rather than just designing one device at a time).
  - b. a focus on art and design both as an application domain and as leading to new design strategies (e.g., the emerging focus on ambiguity).
  - c. an approach of rolling out user experiences and learning from them (we need to be clearer about why and how we pursue this approach)
  - d. -a focus on mixing local and remote collaboration. One criticism I have of ubicomp in general is that much of it focuses on enhancing interaction within local physical space - that is already well served with interactional facilities. A much harder and more pressing problem (given environmental concerns) is supporting collaboration at a distance. Technologies that support distant collaboration provide a major challenge to which we should pay even more attention in future projects.
5. **IRC Mechanisms**, I think that we also need to articulate how the mechanism of an IRC works and why it brings added value. We need to explain how, in the UK, an extended flexible collaboration between several institutions relates to equally large more centralised US laboratories (MIT, Georgia Tech, PARC etc). Politically, we need to provide EPSRC with evidence that the approach has strengths and to sell this to community and industry. We also need to give EPSRC and politicians a positive message from the UK Computer Science community (that in my opinion often seems to be doing so much to shoot itself in the foot).

## Appendix I: Evolving the Equator Vision

I would like to start the process of reconsidering the equator vision by providing some text and thoughts for people to object to. I would like to suggest that we enrich our current vision by removing the separation between the physical and the digital and consider variability of support for digital interaction, as it is manifest in the physical world. The underpinning model is of a universe constructed of interconnected **digitally strong locales** often separated by **digitally light regions**. Within digital locales, we can assume certain levels of support from the surrounding environment both in terms of networked services, sensors and other interactive possibilities such as display surfaces. These locales may be sufficiently rich that users have devices that provide access to a fully virtual environment or may overlay a virtual model on top of the physical world or may allow a rich set of information to be sensed or made available to users. However, devices cannot make similar assumptions when they are located within digitally light regions. Consequently, they need to rely on local computation and on their own interactive possibilities.

### **Sustainable Pervasiveness**

One way in which we can present this diversity of environment is to argue that we existing approaches to ubiquitous and pervasive computing are visionary in nature and postulate a revolutionary shift toward ubiquitous computing often arguing that these environments will come into existence only once we have a ubiquitous infrastructure. Essentially, they take limited account of what happens when users move from environments that are *digitally rich* (for example, research labs with a wide range of available sensors and services) to those that are *digitally light* (with a limited number of sensors and much reduced network connectivity).

In contrast to existing revolutionary stances on ubiquitous computing, the Equator philosophy is to recognise from the outset the variable levels of digital richness visible in the world and to construct both design techniques and supporting infrastructures that recognise this variability as a fundamental feature. Equator accepts from the outset that ubiquitous computing will be an emergent phenomenon and that we need to develop technologies and techniques that recognise this. We seek a shift toward sustainable pervasive computing which recognises the dynamic nature of these environments and the involvement of users in the design, development, deployment and maintenance of these environments. This view of sustainable pervasive environments requires us to focus on three interlinked objectives:

1. The conceptualisation of new forms of sustainable pervasive environments that integrate digital technology and meet the needs of people in their everyday activities. These will embrace support for the domestic, leisure, entertainment, learning and cultural experience that extend beyond new forms of work.
2. The implementation and assessment of new interactive technologies that can be placed in a range of settings to realise pervasive interactive experiences with access to emerging infrastructure services to support the wider information society in a manner which is sustainable.
3. The development of new techniques for the design, assessment and management of digital technologies with a particular emphasis on how the general public can understand and manage these technologies.

In order to elaborate this approach and to develop realistic support, we are particularly interested in the ways in which digital technology can be used to enhance and *augment the spaces within which we live our everyday lives* to form a variety of digital locales, and our *movement within and between these locales* as we cross digitally light regions.

Research will be manifest through the development of new classes of digital technology that exploit this arrangement including technology that is integrated into physical environments, digital artefacts that combine computing functionality with purpose designed physical objects, and technology that is carried or worn on the person.

To achieve this vision of a tapestry of different regions each offering different digital capabilities, we can set ourselves the following basic research objectives:

- To develop **new theories and concepts** to understand how interaction can be supported across a wide range of settings each offering different levels of digital support.
- To generate **new design and evaluation methods** appropriate to these technologies based on a combination of approaches from computer science, cognitive science, social science, architecture, art, design.
- To create **new technologies to establish new relationships** between users, activities and devices across a broad set of environments.
- To develop **new forms of adaptive infrastructure that combines hardware and software** in order to support heterogeneous collections of environments offering different levels of connectivity and computational resources as well as different classes of interactive technologies as users move between these environments.

Realizing these research objectives exploits a number of characteristics that are central to equator.

- We can inform our fundamental research with direct experience of how these technologies can be used to support interaction, exploration, and communication by real users in a variety of everyday settings.
- We can design and develop prototypes of the technologies in direct partnership with users and user communities as a means of ensuring the utility of our research results.

- In addition to disseminating the results of this research to the international research community, industry and user groups, we can directly engage with the general public by placing devices within public spaces, specific work settings and domestic environments.

This also builds upon Equator's twin track approach with focused **research challenges** closely coupled with **experience projects** that apply a combination of technologies and methods to a particular domain. Again we would argue that the key to fundamental research with practical experiences is iteration so that lessons can be learned, fed back into research, solutions developed and then fed back into further experiences.

### **Key Research Challenges**

As they are now activities within experience projects will be supported by fundamental research into adaptive infrastructure (that combines hardware and software), design techniques and assessment approaches. The work on supporting platforms will specifically seek to knit together heterogeneous collections of devices as they move between digitally rich locales and allow them to dynamically alter the functionality they provide. Design techniques will consider how we support mobile activities when the assumptions they can make about the surrounding environment is open to continual change. Assessment approaches will focus on understanding the affordances of different environments and how we may best exploit the potential offered by different digital environments. Each issues offers fundamental research challenges in terms of infrastructure, design and use

#### **Infrastructure challenges**

A pervasive digital infrastructure will interlink a heterogeneous range of technologies. The infrastructure must seamlessly combine reliable high performance computing and communication networks and variable low performance embedded or portable devices with integrated wireless facilities. The supporting infrastructure will need to be open to all legitimate users, promote heterogeneity, and be extremely flexible. Research is needed to ensure that a future infrastructure will promote trust, support rapid customisation, and provide dynamic automatic support.

Equator exploits the long-term nature of its research by exploiting a twin track approach to infrastructure work. A **deployed pragmatic infrastructure** is exploited to gain current usage experiences and to highlight a research agenda for long-term infrastructure challenges as these **advanced infrastructures** mature they will migrate to the deployed infrastructure. We envisage the deployed infrastructure being made widely available to an international community. Areas of research that these advanced infrastructures may consider include

- **Support for trust, security and privacy.** Resources will vary in their availability and their reliability. However, services need to be trusted at the point of use. Fundamental research is needed to enable the realisation of trusted ubiquitous systems formed from the coalition of these potentially uncertain components. In turn, trustworthiness is related to privacy, security, system translucence, and human controllability.
- **Handling uncertainty.** Current infrastructures tend to mask the uncertainty inherent in sensing technologies from users. However, this uncertainty is central to the many aspects of pervasive computing and has played a significant role in the work of Equator to date. We need to consider how best to handle this uncertainty within the infrastructure and to develop new ways of representing this uncertainty to potential users of an infrastructure.
- **Support for evolution and change.** Matching the facilities provided by a flexible infrastructure to the demands of a particular situation lies at the core of successful computational support. The cost of assembly must be sufficiently low that the future users will focus on the work at hand rather than the services and infrastructure supporting it. The goal is to develop easy to use techniques for rapidly assembling software and hardware components.
- **Dynamic autonomic support.** As more of our activities depend on the use of digital services the very complexity of these systems threatens progress. We must develop a supporting open digital infrastructure that is able to handle rapid and potentially radical changes with minimum systems administration. We must provide autonomic self-configuring models to support human interaction.
- **Rapid development of Pervasive Environments.** We already know from equator experience that the cost of development of ubiquitous environments is simply too high. A large amount of bespoke development is needed in order to realise a pervasive environment and we need to find approaches that significantly reduce the cost of development in terms of both effort and time. One way to address this is to exploit ubiquitous style devices as a means of developing these environments.
- **New forms of architecture that combine both hardware and software components.** the relationship between hardware and software infrastructures. With the introduction of the Smart ITs into Equator we are in a potentially very strong position to take this on. We now have a hardware prototyping platform and a range of software platforms (Equip, Elvin ...). This allows us to develop an architecture and integrated toolkit spanning both hardware and software.

#### **Design and Use Challenges**

This set of challenges continues the work we have already established within the understanding interaction challenge. However, we may wish to add to and refine our current set of challenges. Potential issues of importance include:

- **Living with uncertainty.** Core to the development of many of the future environments envisaged by Equator is the monitoring and sensing of activity e.g. tracking a person walking across a city by GPS or putting crockery onto a weight table. An inherent part of that is the digital abstraction and approximation of that activity i.e. sampling, delay, disconnection, outdatedness, uncertainty. There is no getting away from the way that such activity is going to be

interpreted through sensors, transducers, cameras and so on i.e. digitally and with consequent losses/uncertainties as well as gains. Everyone wants to make the gains (new functionality) apparent to people, but doing this in a seamless way is not going to happen unless we learn to accept that the uncertainties and inaccuracies (the 'seams') are an inherent part of a digital medium. People learn to take account of and to use the errors and limitations of a new medium, as an essential part of its new functionality.

- ***Richer Notions of Context*** In UbiComp, context is typically "the location, identity and state of people, groups and computational and physical objects" to quote Dey et al.'s paper from the special issue of J.HCI on context-aware computing. These definitions emphasise absolute features that may be relatively easily tracked or represented, but avoids less methodologically convenient features such as subjective or social aspects of the user experience. In their introduction to that same special issue, Moran and Dourish remind us that "the design of computing artefacts must take into account how people draw on and evolve social contexts to make the artefacts understandable, useful, and meaningful." By taking a deeper, more sophisticated approach to context, we find ourselves amongst the issues at the heart of Computer Supported Cooperative Work (CSCW). After all, what is a system's representation of a person's state or social context if not a description of his or her activity? If a system's representation of context includes users' activity, and users know that they are represented in this way, then each user will face issues of how to present him- or herself to others through the system, and how to maintain useful awareness of others without being invasive. In designing for context, we have to design for collaboration and awareness and, potentially, to design for privacy. In practical terms, a 'deep' ubiquitous computing system is a collaborative system. More generally, consideration of the way that ubiquitous computing systems that are 'out in the world'—in the physical sense as well as the social sense.
- **New forms of community.** A pervasive environment offers the possibility of new forms of community. Facilities are needed to easily form dynamic and transient collaborative groups It is not clear that we have focused on support for the formation of these groupings within equator and considered them beyond the bounds of the experience projects.
- **New kinds of interaction.** Pervasive computing offers the possibilities of new interactive arrangements between computer, devices, users and autonomous agents supporting these users. We have started to elaborate some of these arrangements through the development of our experience projects..
- **New interactive arrangements.** Pervasive computing requires research into new classes of device and the development of multimodal interaction techniques to support these forms of device. The challenges of making these devices exist outside the research lab are considerable and design approaches that provide a ways to sensibly use the variety of sensing technologies represent a real challenge
- **A broader concept of design.** Pervasive computing broadens existing considerations of interactive design to include architectural design, art and design, social and cognitive science. The development design techniques that embrace these viewpoints is central to equator and we are currently making progress on this. Examples of this work to date in equator include the work on ambiguity as a resource for design and the work on seamfullness, seamlessness.
- **Socio Economic Impact.** The deployment and use of devices that pervade all aspects of our everyday life will have significant social and economic impact. We have tended not to consider these as a central part of our research to date n equator although we spent some considerable time considering issues of ethics at our year one review. Understanding these potential impacts may involve a broad range of disciplines (e.g., economists, philosophers) than we currently have direct access to in Equator and we may wish to exploit some of our funding for fellowships in this area or seek additional funding from new initiatives to support this.