Moving Beyond the Application: Design Challenges For Ubiquitous Computing

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ABSTRACT
Weiser predicted a world in which computing moves 'beyond the desktop' and is increasingly integrated into the everyday environment and embedded in everyday practices and activities. We think that, as this becomes a reality, the concept of 'application' needs to be re-thought and broadened, motivating this by a look at key successes in ubiquitous computing. We discuss some of the challenges to design and evaluation methodologies that a broadening of the definition of 'application' might produce.

INTRODUCTION
Although ubiquitous computing by its nature moves beyond the desktop [6], research in ubiquitous computing still tends to be restricted to a desktop-centric view of what constitutes an application. We believe that this view (a) prevents the community from recognising how successful ubiquitous computing comes about; and (b) means that key issues for design, development and evaluation are not being sufficiently acknowledged. To make this argument we draw on examples of successful 'ambient' ubicomp, as well as our own experiences of engaging with ubiquitous computing applications through projects currently being conducted in the Interact Lab at the University of Sussex.

The Interact Lab is primarily concerned with the user-centred iterative design, deployment and evaluation of innovative technologies. Our aim is to design technologies that fit into and enhance quality of life for the people they are designed with and for. In particular we are concerned with embedding applications ('beyond the desktop') in everyday contexts of use, be they home or office or outdoors, leisure or work.

We are not just interested in what is technically feasible but, more importantly, what is useful or desirable, enhancing people's lives and interactions. We consider it critical to conduct research in real-world, 'in the wild' settings with existing homes and public spaces etc, rather than purpose built settings or labs, to explore the very practical issues of situating ubicomp technologies into everyday environments. We also believe that involving people in helping to define what they want to live with is critical.

This implies designing applications for the messy real world *in* the messy real world with the collaboration of its inhabitants. Underpinning all of the projects that we discuss here are the common and fundamental research questions: What is ubiquitous computing for? What are key examples of success? How do we go about finding a genuinely welcome place for ambient, pervasive and ubiquitous computing applications? What methodologies should we use to discover them? How can we engage all sectors of society in the design of applications fundamentally different from currently available applications?

LEARNING FROM AMBIENT COMPUTING
Currently existing 'ambient' computing successes in the real world tell us a lot about what 'applications' are - once we move beyond the desktop. There are already many examples of computing disappearing into the environment in the way imagined by Weiser in his seminal paper that kick-started the field of ubiquitous computing [6].

One example is supermarket shopping, where an enormous amount of technology is arrayed in order to support the consumer's desire to select her own vegetables from an attractively displayed shelf. There is evidence that this interaction is in fact a very primal – the desire to pick fruit from a tree (or shelf) is optimised in the visual system of primates [3].

Another example is the interaction involved in driving a car. Here technology is employed not only in the car to ensure smooth running of the engine and safe braking, even on a loose surface, but also in the traffic lights which control the movement of the car down the road and in the command and control systems which ensure that there is fuel in the pumps at the petrol station. This example highlights another very important feature of many successful disappearing computing applications. The computers that work in them do not form a 'joined-up' system. Data does not flow through them end-to-end but is mediated by mothers on the school run, delivery trucks, shop assistants etc. In both cases, although they may have changed in many small ways, driving and shopping are still recognizable as the same activities that they were 50 years ago when no computing technology was involved.

What these examples show is the mutual dependency and dialectical relationship of computing and human activity in real-world situations. The activities are impossible without computing; equally computing makes little sense outside the context of the activity.

These examples demonstrate ways we need to re-think and broaden the concept of 'application'. The desktop-centric view is 'boxed': The task is clear, with a limited number of means for achieving it at the disposal of a user who is isolated from the world. The user interacts directly with the application through a designed interface. Information flows from the user to the application, which processes it and then returns information, which helps the user towards the goal of her task. This 'boxed' view of what constitutes an application has been revised and informed through research in the field of computer-supported cooperative work (CSCW), which emphasizes the importance of understanding how software applications become integrated into social practices, the ways that the use of many different technologies are interleaved with other methods of communication [1] in the business of getting work done and the importance of real work locations in affecting how technologies are used [5].

Ambient computing means that this perspective, with its ecological, multidimensional approach, becomes central.

Key lessons from ambient computing for redefining applications

One characteristic of many genuinely invisible computing applications is that the computing involved tends to orient itself around pre-existing, valued interactions. In other words, it augments and enhances what people already do.

What can we learn from interactions such as shopping and driving:

1. *Successful disappearing computing applications do not have to replace a current method of interaction. Rather they may augment successful methods of interaction that are already in use.*
2. *Successful disappearing computing applications do not have to constitute an en- to-end flow of data. Rather crucial parts of the data exchange may be mediated by humans or non-digital, physical media.*

These lessons show that we can no longer think of an 'application' in a conventional 'boxed' way, but need to recognise that ubiquitous computing applications fuse human activity and computing that does not exist outside the ecology in which it is realized. It is arguable that this has always been the case, but ambient computing means that it can no longer be treated as an analytic perspective, but poses an urgent reality. The full impact of these observations on the design of ubiquitous computing is quite daunting. Here we discuss some of the possible issues and challenges that such observations bring to light.

Implications for design

A major issue arising out of this new conceptualisation of 'application' is how to do user-centred design. Ambient computing implies that people are not conscious of the fact that they interact with computers as they go about their daily lives buying apples or driving to work. Here, it appears that user-centred design is not needed: only sensitivity to what the human activity is, and how to reconfigure it technologically without interrupting its flow.

However, an ethical issue arises. Invisibility conflicts with the ability to control. An important question is therefore what should be hidden (do users need to know how a network works and which sensors are used?) and what needs to be visible and configurable for users to remain in control – referring both to being able to understand what is happening and to being able to configure this. Thus, even for ambient computing, users need to be engaged.

Another ethical issue of putting the service offered in the foreground of attention arises if side effects are unnoticed. While this matches the vision of invisible computing as allowing people to focus on their goal, there is a downside to this. Many side effects remain invisible or are considered a minor loss in comparison to the services offered, in particular we refer to surveillance and monitoring or data mining. These issues are not in the centre of this paper, but should not be forgotten.

How to engage people as co-designers of novel applications

Not all ubiquitous computing could be called 'ambient'. Many ubicomp applications are highly interactive and anything but 'invisible'. At the some time, ubiquitous computing makes possible new kinds of activity and experiences, which are inherently novel and which extend and change what people can do and experience.

A particular challenge here is that we often cannot build on user's experience – because the user has no experience of what it is that is being designed. This is in some ways similar to the early times of Participatory Design of desktop applications, when users had difficulties envisioning what the system might do and how to interact with it. On the other hand we have found some users to heavily refer to previous experience that keeps them stuck to a certain model (kids participating in skipping trials when asked to picture a scenario how they would like to change the game attempted to imitate the computer games they know).

So, for disappearing computer systems, we need to ask how we can empower users by revealing what computing is happening and how it affects them. And at the opposite end of novel ubiquitous computing: How can we introduce participants in design to the possibilities of ubiquitous computing without simultaneously telegraphing our own ideas about what the archetypal applications for these technologies should be?

Prototyping

We've also encountered the problem that prototyping an ambient computing system is far more resource-intensive than traditional computer applications. Low-tech prototyping (as much as we like it) can be inappropriate if we want to explore these interrelations and to evaluate a system out in the wild.

What constitutes a prototype in an ambient computing environment? If the 'traditional' model of creating a laboratory prototype, which is eventually deployed, first small-scale and then larger scale does not work well in this environment, what other methods might be tried? Is there a way to start at another point in the innovation cycle? This is a real issue: our own experiences show that prototyping ubicomp involves highly developed working models evaluated in actual settings requiring much more work, both in terms of build and deployment in a real ecology, than was formerly the case.

(Captive) Audiences and deliberately 'boxed' situations

One method of circumscribing the problem of designing ambient computing applications for ecologies is to target a potential 'captive' audience whose goals and interactions can to be some degree restricted or dictated. This enables design and testing of the application to be 'put back in the box'. We are slightly concerned that this is the reason for so many ambient computing applications focusing on children in classrooms and (usually elderly) people under medical care who are given little choice as to whether they use the technology. This is not to rule out research on ubiquitous computing for these groups (which we have conducted ourselves) – it rather to point out that the healthy adult population is worthy of study and to ask whether our experiments really improve users lives and respect them.

To some extent this criticism also refers to research within museum spaces. Here the use situation is 'boxed' in terms of being an extraordinary situation with little interference from the outside world or everyday life, but people have a choice to not-interact or 'misuse' the system. In this case we gain freedom to experiment, to see what finds interest and is used voluntarily, while not risking long-term negative effects for users (visitors) in case of failure. Nevertheless we carry responsibility for curators to ensure that the visitors experience is not harmfully effected – for the involved museum staff it is a real-life situation.

Prototyping Intensive and Sparse Use

The non-boxed nature of ambient computing, its interrelation and connection with the entire world (physical, social) has a high impact both on design and evaluation of systems. Thus we not only design a technical system, but also its integration into an existing environment and practices, or a new environment along with new practices.

This means that often there is a 'critical mass' or network effect, with the real value (or problems) of an application only becoming detectable once a certain number of people use it. For these cases, evaluation of the system and its effects is difficult.

This is another reason why we believe that lab-based prototypes are inadequate – we need to go 'out in the wild' and do *situated research*. Being in the users environment, understanding the environment and their practices provides value in itself –the direction of our research is effected by what we encounter, it provides us with new ideas and inspirations, makes us conscious of our assumptions and often even uncovers new opportunities. However, it may also mean that artificial methods are required to simulate the kinds of network effects that would occur should an application become generally deployed.

Our Current Work

Ubicomp for Domestic Environments

Much previous work on the deployment of ubiquitous computing applications into existing homes seems focused on applications that researchers/designers have come up with in isolation. In our own attempt at designing ubiquitous computing applications for the domestic environment we seek to explore with potential users what they would like to have, allowing them to decide whether the emphasis falls on practical or ludic applications of technology. The emergence of toolkits such as the Equator Component Toolkit (ECT) [2] now makes it much more feasible to work with people to brainstorm ideas, and to quickly prototype these ideas to the point where they are deployable. To this end, we have conducted a series of loosely structured interviews with people in their homes as baseline studies prior to engaging in co-design and deployment work. These interviews will serve as a source of inspiration for further user-centred design sessions conducted in the home, which will be followed by iterative deployment and development of applications in homes.

Although this work is in its very early stages, interesting issues are already emerging. For example ubiquitous computing envisages a future in which sensors are everywhere - yet in the houses we visited the sensors that were present were either not used (a burglar alarm) or not working (thermostats).

Participant Design of Interfaces for Configuration (Interactive Skipping)

One of the possibilities enabled by the toolkit environments is that applications need not be a 'build once – deploy once' thing. Instead there are possibilities for people to compose their own applications from basic building blocks or to change the configuration of an application (e.g. setting up a ubicomp burglar detector system). The question is though, do people want to do this, and if they do, how could we make the application transparent enough for them to do this. Also different people might want to engage in this at different levels and need different skills (c.f. changing a light bulb vs. getting a new power outlet installed).

Drawing on our experience of user-centred design for children [4], we have conducted several sessions of participatory design with groups of children of different ages. The design sessions used an interactive skipping game constructed using ECT [2] as a technology probe to acquire a better understanding of the kinds of interface that might suggest reconfigurability of software and hardware components. Findings from these early trials suggest that configurability of hardware and software does not suggest itself easily to children. We have however identified 'character editing' as it is used in games such as "The Sims" as a possible paradigm of use that might be expanded to allow the participant design of applications.

Chawton House

The Chawton House Project is augmenting the grounds of a historic English country house with ubiquitous computing to provide new kinds of visitor experience. Currently, curators tour visitors, in person, around the house but not the garden. They see an opportunity for technology to augment what they do and remove some of the workload from them so that they do not have to do tours in person (particularly when curators have other duties and responsibilities built into their jobs, unlike docents).

One of the key issues for the project is that the experience of the estate is actively created for visitors in personalized tours by curators. The experiences offered are intrinsically interpersonal – they are the result of curators interacting with visitors, and are situated, embodied activities. They are forms of improvisation constructed largely in the moment and triggered by locations, artifacts and questions.

The challenges here are (a) to understand current practice around giving tours; (b) to engage with curators in envisioning and creating future IT that will appropriately integrate with and extend that practice in ways that are relevant and valuable to them.

A basic lesson emerging is the difficulty of engaging in co-design of new forms of activity around new kinds of technology. These are hard to prototype using traditional means such as paper or Powerpoint. Rather, what is required is hi-fidelity demonstrators that both shape and ground concepts so that they can be understood and developed. Again, we are needing to think about what an application is in new ways: it is not so much a 'solution' for an existing well-known 'problem space' but a creative response to an 'opportunity space', the opportunity being created by the availability of new technology, and by the willingness of users (Chawton House staff) to move beyond their existing practices and activities. Doing this means creating and refining experiences at high levels of fidelity and using these to progressively articulate the application. This leads into issues of needing to massively engineer demonstrators, and also the risk of over-commitment.

CONCLUSION

We can learn a great deal from current successes of ambient and ubiquitous computing, but only if we decide to take on the challenges for design and evaluation that these successes present. If we acknowledge that ubiquitous computing applications do not necessarily have to be complete curators of the flow of data nor do they have to replace an existing preferred method of interaction, many further interesting and valuable applications of ambient and ubiquitous computing may be discoverable.

We feel that situated research in collaboration with users is essential to understanding how ubiquitous computing might become integrated into everyday life. Many ideas that at first sight are not really novel and easy to implement as a lab experiment gain in complexity when targeting a real environment for use, as the physical, cultural and social embedding of the system needs to be designed, requiring an understanding of this environment, which then might spark new ideas. Thus we do not believe ubiquitous computing in the service of users to be a fantasy. Yet we feel that often overlooked is the work and the self-reflection and critical inspection needed to make it work and make it serve real users (not imagined ones).

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