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A Historical View of Context

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Abstract. This paper examines a number of the approaches, origins and ideals of context-aware systems design, looking particularly at the way that history influences what we do in our ongoing activity. As a number of sociologists and philosophers have pointed out, past social interaction, as well as past use of the heterogeneous mix of media, tools and artifacts that we use in our everyday activity, influence our ongoing interaction with the people and media at hand. We suggest that one's experience and history is thus part of one's current context, with patterns of use temporally and subjectively combining and interconnecting different media as well as different modes of use of those media. One such mode of use is transparent use, put forward by Weiser as ubicomp's design ideal. One theoretical finding is that this design ideal is unachievable or incomplete because transparent and more focused analytical use are inter-dependent, affecting and feeding into each other through one's experience and history. Using these theoretical points, we discuss a number of context-aware system designs that make good use of history in supporting ongoing user activity.

Key words: adaptation, appropriation, context modelling, system design, theory, ubicomp

1. Introduction

Context and awareness are at the core of both CSCW and context-aware computing, albeit with different interpretations with regard to theoretical principles and design practice. An extreme view, deliberately highlighting differences, might hold them as incompatible or conflicting: CSCW focuses on intersubjective aspects of context, constructed in and through the dynamic of each individual's social interaction, and defends against reductionism and objectification. In contrast, context–aware and ubiquitous computing often concentrate on computational representations of context that span and combine many senses and media-rather than the social construction of context in interaction. In the introductory article of a recent special journal issue on context-aware systems, Dey et al. (2001) describe context as ''typically the location, identity and state of people, groups and computational and physical objects''. Such definitions are common in context-aware and ubiquitous computing, but they do tend to emphasise objective features that can be tracked and recorded relatively easily, and to de-emphasise or avoid aspects of the user experience such as subjectively perceived features and the way that past experience of similar contexts may influence current activity–issues which are central concerns of CSCW. However, as this special journal

issue exemplifies, both fields increasingly recognise the need for bridging or even synthesis.

This kind of discussion and this kind of dichotomy have appeared before in HCI and CSCW, and it would seem appropriate to draw from that experience here. There is a long-standing discourse on the conflict between the infinite and subjective detail of social interaction, and the finite and objective aspects of systems design. One key issue has been how systems can represent work and its context without over-formalising, over-simplifying and over-objectifying it. A canonical example in CSCW is the attempt by Winograd and Flores to make theoretical discussion and system design inform each other in the *workflow* design approach, as implemented in a system called The Coordinator (Winograd, 1986). The Coordinator was essentially an email tool in which the system supported one's work not only by presenting the content of each document for editing, but by presenting the document's context within a flow or temporal pattern of social interactions, such as a request from someone for its creation and the promise to deliver it to someone else once complete. Workflows were thus 'conversations for action' built from a pre-designed categorisation of work interactions. The system gave users an explicit representation of the process of work as well as the documents, spreadsheets, reports and other artifacts handled and constructed within the work process.

Winograd and Flores drew on a number of experiences and theories, but central among these was the hermeneutic philosophy of Martin Heidegger (Heidegger, 1927/1962; Grondin, 1994). In particular they focused on Heidegger's phenomenology and ontology, in which human activity is treated as an ongoing temporal process of language and interpretation, rather than a series of separable perceptions, each of which frames and fixes the world as a set of symbols or signs. He (and they) treated language as activity, and activity as language, i.e. language was seen not merely as a mode of representing things, but as a mode of doing things. By formalising and making explicit the temporal flow of such actions, Winograd and Flores aimed to make work 'present-at-hand', in that people in an organisation would use the workflow as a way to consciously focus on their work, rationalising it and making it more efficient.

Such workflow-like representations of activity are being brought into context-aware computing. In Activity-Based Computing, (Christensen, 2002; Bardram, 2003), a direct connection is made between context-aware systems design and the formal models of activity in workflow and Activity Theory (Nardi, 1996). In their healthcare systems for hospitals, patient treatment is organised and managed through a set of defined tasks or activities that have been decided upon by all clinicians. Each clinician's work activity is represented as a heterogeneous collection of computational services, and such services are made available on various stationary and mobile computing

devices. A related system design approach is the 'task driven computing' approach of the Aura system (Garlan, 2002), in which tasks are 'explicit representations of user intent' constructed out of 'coalitions of abstract services' within the system.

However, such representations of activity have a potential danger, namely "that their design is predicated entirely by formal procedures – ignoring (and even damaging) the informal practice" (Bardram, 1997), and this leads to a paradox or tension that Bardram summarises well:

> On the one hand, due to the contingencies of the concrete work situation, work has an *ad hoc* nature. Plans are not the generative mechanisms of work, but are 'merely' used to reflect on work, before or after. On the other hand, we find that plans, as more or less formal representations, play a fundamental role in almost any organisation by giving order to work and thereby they effectively help getting the work done.

Such pre-designed formal categorisations and representations of work can be useful as resources for action, and as resources for accounting for one's action, but tightly structured representations of work raise concerns in CSCW. A good proportion of mainstream CSCW researchers have focused on revealing the same detail of socially-constructed situated action that is excluded from these representations. It may be expected that a context-aware system's task models will be examined to show whether they are designed with the intention or assumption of being carried out with script-like consistency, instead of being seen as flexible map-like resources for the situated action of users (Suchman, 1986), how much work is needed to make their use fit with the use of other work media, beyond the workflow system, that may not be easily tracked or controlled by that system (Bowers, 1995), and whether they fully represent the dynamics, detail and articulation of users' intents and priorities (Bannon, 1997; Schmidt, 1997).

A contrasting approach to combining CSCW and context-aware systems emphasises socially-constructed situated action, and is also inspired by some of the foundational work of ubiquitous computing. The *embodied interaction* perspective on HCI (Dourish, 2001) binds together CSCW and context-aware computing issues in presenting everyday human interaction as non-rationalising, intersubjective and bodily activity. It treats interaction and context as dynamic achievements of the people involved, and as involving the wide range of media and senses that are involved in their bodily activity. It draws upon sociology, especially the ethnomethodology of Garfinkel (1967), and upon philosophy, in particular the phenomenology of Schutz (1932/1967) and Merleau-Ponty (1945/2002). Garfinkel drew heavily from Schutz, and the use of the word *embodiment* stems from Merleau–Ponty.

Where The Action Is makes it clear that embodiment is an issue to address in design practice, but does not provide specific practical design guidelines,

offering instead statements that help sensitise designers to general issues. Two key examples are *users, not designers, create and communicate meaning* and *users, not designers, manage coupling*, where 'coupling' refers to the process or activity of contextualisation i.e. fitting an object or reference into the non-rationalising, intersubjective and bodily activity that makes up a person's everyday life. More recently, Dourish did apply this embodied interaction perspective to the design of context-aware systems (Dourish, 2004), and he focused on a question highly relevant to this special issue: ''how can sensor technologies allow computational systems to be sensitive to the settings in which they are used, so that, as we move from one physical or social setting to another, our computational devices can be attuned to these variations?''

The key distinction or dichotomy he puts forward is between physical or positivist notions of context, which centre on objective representation of social and interactional phenomena, and social or phenomenological notions of context, which centre of a view of context as a subjective and situated aspect of people's interaction. He points out that the design practice of context-aware and ubiquitous computing is in objective or positivist notions of context, even though its ideals are bound up with social and phenomenological notions. Dourish refers to the Weiser's *Scientific American* article (Weiser, 1991), which uses the work of social anthropologists such as Lucy Suchman and Jean Lave, and hermeneutic philosophers such as Martin Heidegger and Hans–Georg Gadamer (Gadamer, 1960/1989; Warnke, 1987). Similarly, he refers to Abowd (2002), which cites activity theory, situated action, distributed cognition and ethnographic studies as important resources for ubiquitous computing. He suggests that the field's ideals of combining the social and the technical have not yet been achieved: ''turning social observation into technical design seems to be problematic'' and ''these two positions are incompatible''.

Dourish's paper puts forward an interactional view of context based on the embodied interaction perspective, most particularly ethnomethodology, and uses this view to offer three system design principles. These are intended to allow forms of practice to emerge and evolve, rather than requiring users to fit their work and their information to predefined patterns. First, systems should display their own internal state and configuration to users, so as to allow the user ''to make continual determinations of the potential consequences of their actions and their opportunities to reconfigure or realign the technologies through which they are conducting their actions''. Second, deep system structure should be revealed so as to support system inspection and adaptation, i.e. the system's internal structure becomes a resource for the work of adaptation and contextualisation. Third, interfaces should offer ''direct experience of the structures by which information is organized'', e.g., in spatial hypertext structures, ''structure emerges in the course of a

user's interaction, rather than having to be specified all at once or in advance of the actual data being incorporated.''

These design principles are a move in a useful new direction, but there are difficulties to face. Opening up the deep structure of the implementation means designing a presentation or account of system structure and behaviour that is comprehensible and manipulable by users. Presumably we cannot reveal every detail of the entire system all the time, and so we will have to be selective and, to some extent, reductive with regard to the features and processes we open up. The adaptation mentioned in the second principle may let us make this selection and reduction a dynamically changing choice, rather than a design choice made *a priori,* but a system design would have to address the finite experience and understanding of the individual user with regard to system structure, possibilities for reconfiguration, and potential consequences. A 2D information space may offer advantages of overview of information structure, and serve as a workspace for negotiation and articulation of changes to the system, but the issue of how to graphically present and interact with the system seems very challenging given the complexity of current structure and of current use, and systems' openness for new configurations, uses and interpretations. Suggesting that we ''find structures that are visually salient to users, such as clusters, piles, columns, tables, etc.'' rather begs the question: clusters, piles and tables of what? The users have to find structures that are salient to the context, with all the dynamism, subjectivity and openness that Dourish correctly points out to be key characteristics of context. As we will return to later, it also may appear strange that Dourish is proposing fairly explicit and conscious use of the system here, which rather clashes with the ideals of embodied interaction and the 'transparency' of the tool promoted in embodied interaction and ubiquitous computing.

These design principles may be challenging to the designer, but the challenge facing the users is perhaps greater – if indeed structure only emerges in the course of a user's interaction, and if the 'achievement' of context and activity is as isolated and subjective a choice as suggested by this sociology and phenomenology. We suggest, however, there are aspects of interaction and context that this view and these principles do not address. There are influences and constraints on the meaning and use of a system design, beyond or prior to the person or people in the situation of use i.e. from within the design and without.

We suggest that it seems too narrow to say that users, not designers, create and communicate meaning and or to claim that users, not designers, manage coupling and contextualisation. Even if designers do not predetermine the meaning, coupling or contextualisation of a design, they do influence and constrain it. They cannot avoid doing so, because any

computer system that affords representation and awareness of human activity necessarily involves a degree of reduction and objectification, due to the formal representational schemes of programs and databases, and finite capacities for storage, communication and calculation. Any digital system is finite and physical, with limits to what it can record of people's activity, what it can represent internally, what mechanisms of adaptation are encoded in those internal representations, and what external representations such as output devices it can use. Any design makes manifest designers' implicit and explicit assumptions with regard to how to reduce, formalise or objectify context and activity i.e. the choice for the system designer is not *whether* to reduce, objectify or constrain users' context, but *how* (Chalmers, 2003). The designer cannot predetermine users' activities, meanings and interpretations, but also cannot be uninvolved. The designer has no choice but to influence the meaning that users make, and cannot avoid influencing the ways that they manage coupling and contextualisation.

While we gain from understanding the detail of context and social interaction, and aiming for consistency with strong and well-founded theory, we must take a pragmatic stance if we are to design the finite and formal representations that constitute context-aware and CSCW systems. Embodied interaction is a good exemplar of research in CSCW and context-aware computing that begins to bridge between useful practice and strong theory, but it seems that there are still difficulties and limitations to address. In the following sections, we focus on the theoretical ideals for ubiquitous and context-aware computing that Dourish, Weiser and Abowd et al. present, aiming to reassess them in terms of their strengths, weaknesses and alternatives, i.e. as theory 'in itself' and in terms of how such theory reflects or drives design practice. We focus on the underlying theories, assumptions and priorities of ubicomp and context-aware systems design, in particular ubicomp's ideal of transparent or invisible system use. We increasingly concentrate on the way that, over time, that mode of use depends on and is interwoven with rationalising conscious activity. An associated paper (Chalmers, 2004) draws upon hermeneutics and the structuralist semiology of de Saussure (1906/1983) in discussing the way that this historical process interweaves the heterogeneous media we use in everyday life, but in this paper we focus on the way that it interweaves heterogeneous modes of use. We will, admittedly, neglect an important topic: the future, as evinced in plans and expectations, as we concentrate on the past as a resource for the present. Later sections of the paper shift our attention from theory to system design practice, drawing on the earlier theoretical sections as well as the system design work of the author and his collaborators in Equator (www.equator.ac.uk), and the work of other groups active in ubicomp and context-aware systems.

2. The historical development of 'context'

The view of context that holds sway in CSCW, and is exemplified in the work of Dourish but also in the writings of Weiser, is rooted in texts such as *Studies in Ethnomethodology* (Garfinkel, 1967) and *Plans and Situated Actions* (Suchman, 1987). These are primary texts for CSCW's user studies and system critiques. Ethnomethodology (EM) itself has roots in the phenomenology of Schutz, which, in turn, built on Heidegger's hermeneutic phenomenology and the later philosophy of Wittgenstein (1958). Heidegger may be one of the most influential yet least recognised influences on CSCW, context-aware and ubiquitous computing. The centrality of Heidegger to ubicomp is hinted at by the first lines of Weiser's Scientific American article, which used Heidegger's notion of the disappearance, transparency or invisibility of a tool – a notion which has become emblematic of the ubiquitous computing approach.

As pointed out above, the extension of such sociology and philosophy into the heart of the design practice of CSCW and context-aware computing has been problematic, despite the intentions of Weiser, Dourish and others. Some possible reasons for this were briefly mentioned earlier in this paper, and here we try to expand on them by looking at critiques and advances made by later sociologists and philosophers. We aim to better understand such theory's strengths, weaknesses and successors. In particular, we focus on understanding which aspects of activity, use and interpretation such standpoints address, and which they do not, and the apparent dichotomies and paradoxes characteristic of such theory – which we suggest have been at the heart of our field's difficulty in applying theory to system design in both CSCW and context-aware computing.

Anthony Giddens submitted EM to what he called a 'constructive critique' (Giddens, 1995), and this and related work such as Giddens (1984) may be useful to us. He points out five distinguishing themes in and strengths of EM: its emphasis on human action or agency, which most of the earlier leading schools of sociology had lacked; the capacity of human agents for self-reflection, which he suggests most orthodox forms of sociology had considered a 'nuisance' even though the philosophers hold it as integral to human action; language conceived of not simply as a set of symbols or signs, but as a 'medium of practical activity' i.e. as a mode of doing things and not merely a mode of representing things; the temporal and contextual locating of action within what has been said and done by the actors in a setting or scene, and anticipation of future courses of action; and, finally, transparent or 'taken for granted' understandings drawn upon by actors as ordinary, but unexplicated or non-rationalised, conditions of social interaction. EM's emphasis upon this last theme in is one of its direct points of connection to hermeneutics.

However, ''acknowledging the importance of agency in social theory has to be complemented with 'structural' analysis. Ethnomethodological studies are concerned with the production of society, as a skilled accomplishment of lay actors, but much less with its *reproduction* as a series of structures.'' This is not to suggest that structures such as linguistic grammars, legal restrictions and statutes, and organisational hierarchies and procedures stand prior to or above individuals' situated action. Older approaches in sociology and related fields often relied on rules, laws and concepts that were believed to determine the lives of the people who were described in terms of those structures, despite those people being unaware of their existence or influence. Giddens describes such views of structure as naïve conceptions, in which structure ''appears as 'external' to human action, as a source of constraint on the free initiative of the independently constituted subject'' (Giddens, 1984, p. 16). Instead he proposes that ''social systems, as reproduced social practices, do not have 'structures' but rather exhibit 'structural properties' and that structure exists […] only in its instantiations in such practices and as memory traces orienting the conduct of knowledgeable human agents'' (p. 17).

As expressed in Garfinkel (1967, p.11), EM refers to ''the investigation of the rational properties of indexical expressions and other practical actions as contingent ongoing accomplishments of organized artful practices of everyday life.'' It focuses on practical consciousness, i.e. the transparent activity that actors in a setting do not have to rationalise or explicate to each other. However, not all activity is like this. Sometimes one does rationalise and reflect on what one does, but this is not EM's focus. Similarly, EM concentrates on and revels in the indexical: the expressions and activities that are conditional or reliant on context for significance. Suchman contrasts indexical expressions with, for example, ''definite noun phrases whose meaning is claimed to be specifiable in objective, or context-independent terms'' (Suchman, 1987, p. 59). Obviously, we use and rely on indexical expressions and practical actions, but we also continually use and rely on more objective terms and context-independent structures, and hence the decisions, designs and activities of people far away and in the past. We continually create and develop new structures, activities, systems and designs, constraining other people's activity as well as creating new possibilities for action.

EM tends to underemphasise the long-term dynamics and world-wide scale of interaction, in particular the way that people create, deploy and use relatively 'objective' structures such as organisational procedures, legal constraints, and system designs. The designers of such procedures, laws and systems create both constraints on and resources for others' activity. The issues of who creates meaning, who manages coupling and contextualisation, and the influence of the system designer and the system on use and users appear again here. It seems too narrow to focus only on indexical, non-rationalising transparent activity, when such activity leads to and draws from

structure, rationalisation and objectification. "Only for ethnomethodology is the analysis of practical consciousness a circumscribed 'field' of study. For all other types of research the interpretation of practical consciousness is a necessary element, implicitly understood or explicitly stated, of broader features of social conduct" (Giddens, 1984, p. 328). Giddens states (p. 332) that he could not better Wilson's account of the reflexive relationship or 'duality' of structure and situated action (Wilson, 1983):

> "the social world is constituted by situated actions produced in particular concrete situations, that are available to the participants for their own recognition, description, and use as warranted grounds for further inference and action on those same occasions as well as subsequent ones. Situated actions are produced through context-free and context-sensitive mechanisms of social interaction, and social structure is used by members of society to render their actions in particular situations intelligible and coherent. In this process, social structure is an essential resource for and product of situated action, and social structure is reproduced as an objective reality that partially constrains action. It is through this reflexive relation between social structure and situated action that the transparency of display [the mutual intelligibility of conduct] is accomplished by exploiting the context-dependence of meaning".

Over time, even the most objectifying views of the world can become part of language and culture. Scientific tools and techniques are used in an everyday way by scientists, of course, becoming part of their professional culture, but they also seep out into wider culture through documentaries, journalism, literature, and so forth. The representations, symbols and notations of science are part of language and, putting it metaphorically, are "new boroughs with straight regular streets and uniform houses" set within the larger 'city' of language (Wittgenstein, 1958). The key issue for us here is the way that objectifications are constructed by people within this larger social system, as are other interpretive frameworks. People 'do' objectification, conscious reflection and rationalisation, as well as the non-rationalising, intersubjective and bodily activity that makes up much of one's everyday life. We are continually developing new ways of understanding and acting, new objects and processes, and new ways of interpreting what was familiar and everyday. They may begin as starkly detached and objectifying, but as we build up individual and subjective histories of how to relate such new tools and interpretations to the others we use in our lives, they become mundane, everyday and unremarkable: they 'disappear' or become 'invisible' – for a while.

Giddens points out that later forms of phenomenology than the one Garfinkel drew from took fuller account of the way that objective structures, past activity of others, past interactions with others, and previous individual

reflection and action, influences current interpretation, reflection and action: "'Hermeneutic phenomenology' in the hands of Heidegger and Gadamer breaks with the subjectivism characteristic of the earlier phase of development of phenomenology. (Schutz never managed to complete this break.)" Giddens' description of the duality of structure and activity draws on older concepts such as the 'hermeneutic circle' through which one's current understanding, interpretation and action are influenced by one's past experience, and yet also extend and shape one's experience, and Gadamer's concept of 'historically effected consciousness' (Gadamer, 1960/1989; Warnke, 1987).

3. Transparency as an unachievable or incomplete ideal

Objective and subjective are bound together by histories of use and activity, and this is central to Heidegger's concept of the transparency of a tool or technology (Heidegger, 1927/1962; Grondin, 1994). Weiser used this as a core concept when laying the foundations of ubiquitous computing, and his ideal was for the systems we design to be "literally visible, effectively invisible" or, we suggest, objectively visible but subjectively invisible. As he put it in Weiser (1994a):

> A good tool is an invisible tool. By invisible, I mean that the tool does not intrude on your consciousness; you focus on the task, not the tool.

An old example from Heidegger is the way that a skilled carpenter engaged in his work acts through the hammer, focusing on how it changes and is combined with other tools and materials, rather than focusing on the hammer in itself. Heidegger called this transparent, practically engaged and non-rationalising use 'ready-to-hand', in contrast to the rationalising, objectifying and abstracting activity he categorised as 'present-at-hand'. He saw both modes of use as being set within the ongoing circular process of interpretation, in which one is influenced by understanding and past experience of tools and media when using any tool or medium. One's use of a new tool (or a new use of a tool) in the course of everyday, situated and social interaction, combining it with the heterogeneous others used in everyday life, adapts experience and understanding – that will affect how one acts and interprets in the future. In time, this process of accommodation and appropriation lets one focus on the use of the tool, and not on the tool in itself, thus making the tool 'disappear' as Weiser later discussed.

Dourish similarly called for a move towards design of interactive systems that have a better fit with everyday human activity, understanding and interaction, and with the practically engaged and non-rationalising mode of activity characteristic of much of (but not all of) everyday activity. Weiser and Dourish focus on raising our awareness of embodied interaction, i.e. the

interpretation and use of a system by a user in a ready-to-hand way. However, in moving away from traditional HCI and interactive systems design, Weiser and Dourish focus almost entirely on design to support embodied or ready-to-hand interaction. Following writers such as Schutz, Garfinkel and Suchman, they do not fully address the relationship between the two modes. In particular, how does a tool *become* transparent and ready-to-hand?

The previous section began to lay out this process. Heidegger, and his successors such as Gadamer and Ricoeur, held that situations where a tool becomes present-at-hand are crucial to the individual's learning and to the differences between individuals. The ongoing 'feedback loop' of interpretation and understanding integrates these two modes, and social interaction affords variation in people's understanding as well as consistency in their behaviour. For example, creativity can be considered as the variation of an individual's subjective understanding from his or her prior understanding and from others'. The individual may be very conscious of his or her own activity, rationalising it and very aware of it, i.e. the system or tool is present-at-hand, for a while.

A most important situation here is the accommodation and appropriation of a new technology into a setting or community of use. As pointed out in Schmidt (1997) and in Chalmers (2003), a system, like any formal and finite construct, necessarily involves under-specification of the situation of its use, and therefore openness to interpretation and variability of its normative effect. This allows the individual user to conform to a script-like pattern of actions, or to treat the system as flexibly interpreted, map-like resources for situated action. People accommodate the characteristic affordances of a new tool, but they may also appropriate it to suit and adapt the practices and priorities of their own contexts and communities of use i.e. other, older tools and media, and other people. With experience of its use, the tool may become understood and familiar to the individual, i.e. more ready-to-hand, embodied and transparent. Similarly, as people perceive one another's use, with each interpreting and reacting to the others, they can achieve intersubjective consistency of behaviour – consistent with each other, but not necessarily with the use expected by the designer. A use or activity that is new and present-at-hand for one of them can thus become transparent and ready-to-hand for all. The circular process of interpretation, whereby perception and activity are influenced by understanding and experience, but also feeding into and changing them, relies on the interplay between ready-to-hand and present-at-hand interpretation.

Embodied interaction, as Dourish and Weiser made clear, is an aspect of human activity that was under-emphasised in HCI. Nevertheless, ready-to-hand embodied interaction and present-at-hand objectification are interdependent – and neither author addressed this. In simpler terms, the context of use is founded on both objective and subjective interpretation, with each

influencing the other over time. We have to expect that a new technology will be to some degree present-at-hand, no matter how well the designer aims towards embodied or ready-to-hand interaction. This is just one of a number of modes of use and interpretations that neither Weiser nor Dourish fully dealt with.

Dreyfus, summarising Heidegger, suggests three categories or modes of present-at-hand activity, which we label here as breakdown, analysis and contemplation (Dreyfus, 1991, p. 124). In the case of breakdown, one might continue with a different tool, use deliberation to eliminate the disturbance in the original tool, or stop because one can determine no way to continue with it. In breakdown, the affordances of even the most familiar tool may significantly differ from those of everyday ready-to-hand use e.g., when the head of the carpenter's hammer becomes loose, so that he becomes very aware and conscious of it, and of the difficulty of progressing with normal use. Another example might be the breakdown that occurs with a mobile phone when it loses its network signal: one's attention may turn from a conversation 'through' the phone and its infrastructure, to the tool itself.

A second mode of present-at-hand activity is analysis, for example skilled scientific activity, observation, experimentation, theoretical reflection or even wonder. Use of the tool or system is not transparent, and one cannot ''focus on the task not the tool'' because the task *is* to focus on the tool. The carpenter may work on the hammer, to fix it; the phone user may focus on the signal strength indicator, waiting or moving until he or she regains a signal; a researcher may study how a new mobile technology works in use; and, as Dourish suggested, an individual user may explicitly use the visualised representation of system structure so as to adapt it. A third form of present-at-hand activity is contemplation, which covers the cases in which one may be finished with a tool or resting from using it, and be engaged in less analytical reflection or curiosity towards it.

Dreyfus did not explicitly cover or address activity that was skilled and conscious, but social. In doing so, he accurately summarised Heidegger's tendency to narrowly focus on the individual. One of the ways that Heidegger's successors, particularly Gadamer and Ricoeur, advanced hermeneutics was to fit such social interaction into Heidegger's framework (Warnke, 1987; Grondin, 1991). The ongoing 'feedback loop' of activity, interpretation and understanding also serves to integrate the different modes of use by different people. Social interaction affords consistency in people's understanding and behaviour, as well as inconsistency as they accommodate the characteristic affordances of a new tool, and appropriate it to suit their own contexts and communities of use.

One might then usefully define a fourth mode of present-at-hand activity, self-presentation, based on skilled, social activity involving conscious consideration of how a tool mediates one's activity i.e. presents one's activity

to others. Examples include when one consciously considers how to demonstrate or teach the use of a tool to someone else; avoiding a web site or a surveillance camera, or turning off an active badge, because it may lead to one's activity being presented to others in embarrassing or invasive ways; and using GPS logs to spell out a name on a cartographic scale, as in GPS drawing (www.gpsdrawing.com), so that others can see where and how one moved.

Each of these categories of use and interpretation, i.e. transparency, breakdown, analysis, contemplation and self-presentation, is influenced by prior activity and experience, and also influences later activity. In other words, each affects and is affected by the others. This hermeneutic circle, whereby perception and activity are influenced by understanding and experience but also change understanding and extend experience, is thus an abstract description of the historical process that makes these different modes of use interdependent.

The most profound technologies may be those that disappear, as Weiser said at the start of his Scientific American article, but it may be clearer now that *they* do not weave themselves into the fabric of *our* everyday life. Instead, we weave them into our lives, in and through our use and activity. Disappearance happens through the process of coupling and contextualisation i.e. the circle of interpretation, action and experience that weaves together both ready-to-hand and present-at-hand uses of a tool by people over time. The objectifying use of tools and information is a constraint, influence and a resource for new forms of interaction, for sharing and learning, and is a precursor and foundation for transparent everyday use. Similarly, transparent use builds experience and understanding that are influences and resources for objectifying, rationalising use. It seems that a degree of care has to be taken when treating embodied interaction, disappearance and invisibility as an ideal for context-aware and ubiquitous computing.

Mark Weiser suggested that even a "glass TTY UI can be ubicomp" if its use is well woven into the fabric of people's collaboration and interaction (Weiser, 1994b). Again, this may seem contradictory to the common notion of ubicomp and context-aware systems, involving technologies such as location sensors, mobile displays and wireless communication, but Weiser was clear that it was not the technology in itself that made for ubicomp. Instead he suggested that we should aim for and support the accommodation and appropriation of computing into everyday life, so that its use is non-rationalised, intersubjective and interwoven with our use of other media. What he perhaps did not fully deal with was the way that rationalised, objectifying and focused activity is necessary to the process of achieving his ideal, and therefore that his ideal is unachievable or incomplete without complementary modes of activity. A challenge for system designers is, therefore, how to design systems that reflect this broader view of context and

activity, and which use history and time to interweave different modes of use, media and people so as to support the accommodation and appropriation of computing into everyday life.

4. Historically effected systems

One key systems design issue to draw from this theoretical discussion is the importance of history to context and use. Although future expectations clearly play a large part too, here we will concentrate on the past. In particular, we suggest that past interactions with people and systems, and the structures of those experiences, seem underrepresented in the practice of context-aware system design. Individuals' past interactions are a manifest influence and resource for their action and interpretation, but are not often in our systems' models of context.

There are some examples of systems' use of the past, of course. Focusing for the moment on the museum setting, which has been a significant area of application for context-aware systems, HIPPIE adapted the presentation of information in a museum, and presentation of the attributes within the system's database, based on a record of what displays and related information a visitor had seen before, either in the museum or previously (Oppermann, 1999). The system of Schiele (2001) captured video images of paintings in a museum tour, and then would later automatically retrieve video recordings of the tour guide if one later came across the same paintings (or realistic enough reproductions). A rather simpler example was the HP Cooltown Rememberer system, which built up a visit record, consisting of a set of web pages. Users left the museum with an artifact that was intended to remind the user of the visit and which contained a URL for the visit record, for example a fridge magnet with an embedded RFID tag (Fleck, 2002).

Taking such systems as representative of the wider area of context-aware systems design for the moment, we suggest that there has been a tendency for context-aware systems' use of the past to focus quite narrowly on the objects and locations used in the past by one person, and not how that person used them in the course of social interaction with friends or colleagues, for example, or how other people used those objects and locations in their interaction. Also, we rarely show or take advantage of the temporal structure of past use, for example the actions and interactions that preceded, co-occurred with and followed each recorded use.

One of the few systems that take advantage of patterns of co-occurrence in use is the 'Smart Its Friends' technique for establishing connections or associations between artifacts (Holmquist, 2001). This relied on correspondences in implicit or explicit movement to discover associations between

subsets of a collection of small devices, such as the objects one usually carries in a shoulder bag or briefcase as one leaves for work. These objects were part of each other's context, or part of the same context, if they were used along with each other, which is a distinctly structuralist approach (de Saussure, 1906/1983). It would seem, however, that Holmquist et al. never took the further step of using such patterns as a social resource, building up data on use that would serve as a resource for others as to what devices to combine, where to use them, and what new devices to find out about or obtain.

Some systems have used such data as a social resource, for example *Social Net* (Terry, 2002), which used patterns of collocation or proximity to support social introductions and networking. In Equator's *George Square* system, we also made the past a resource in this social way, but we employed a broader or more heterogeneous set of media for people's use, and made the use of the past more explicit. George Square is designed to aid pairs of tourists during a visit to the city, and its first user trials have just finished. It runs on a tablet PC or laptop, and involves several connected tools and devices: GPS, 802.11, a VoIP audio link, a web browser, a small webcam and a 2D display (Fig-

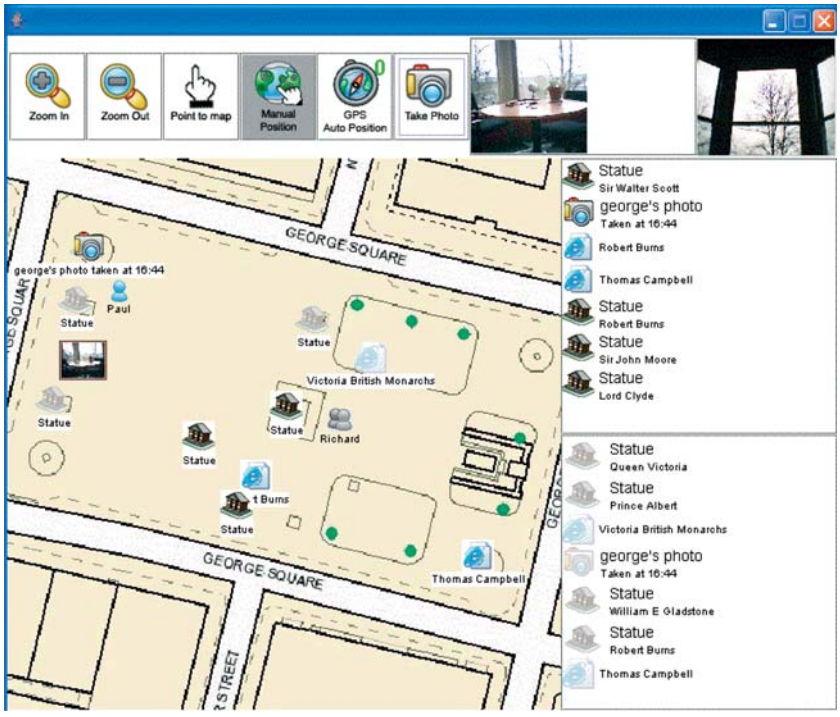

Figure 1. The George Square system offers synchronous awareness of users' locations and photography, and awareness of selected parts of the history of movements, photography and web page use, as chosen by the Recer recommender subsystem.

ure 1) that centres on a map of the city centre. Each visitor has such a tablet, and sees on his or her map both visitors' locations. A visitor can present his or her location to the system, and to the other visitor, either implicitly or explicitly, i.e. via GPS, or by dragging his or her own icon across the map. When one visitor takes a photograph, it is shown to both of them. It is shown in a 'filmstrip' at the top of each visitor's display, and in smaller form at the location of the user who took it. One of the influences on George Square's design was a study of tourists in city centres (Brown, 2003), which highlighted the sharing and discussion over maps, guidebooks, accounts and photographs from past visits before, during and after the visit.

The ongoing activity of each individual, in terms of locations, photographs taken and web pages loaded, is logged, forming a history for each user. By using a variant of the *Recer* recommender system (Chalmers, 1998), we use these histories to make recommendations of places to go, photographs to see and web pages to read. Recommenders (Goldberg, 1992; Resnick, 1997) generally do not use time or location to make context-specific recommendations. While there are other temporally specific recommenders that start to broaden the model and use of context, such as *Jimminy* (Rhodes, 2003), the collaborative use of history and the heterogeneity of the set of media involved distinguishes this system from others. Recer finds past periods of activity in the user histories that share some of the locations and URLs one has used recently, and selects other locations and URLs from these periods as recommendations. The recommendations that a visitor receives are shown on his or her map, and are also listed in order of estimated relevance. He or she is made aware of the other visitor's recommendations, shown ghosted on the map and in a second list, so that each visitor not only has as a resource individually-tailored selections of the past, but can talk about and compare them with their co-visitor, and fit them into their current activity.

The George Square system also creates a 'blog' from each visitor's activity, which they can use via the web to remind them of their past experience and as a resource for future visits and discussions with others. The blog page shows the temporally-ordered list of locations and URLs from the visitor's log, which he or she can select from and edit. A map tool much like the one used on the tablet during the 'street use' shows a spatial representation of the selected and/or edited log data.

In our ongoing work, we are taking the notion of recommendation somewhat further. Patterns of use can lead to good recommendations for people, but we are interested in exploring whether tracked features such as locations, web page use, GPS availability, network access and so forth can be combined with tracking the use of the components within a system. In this way we hope to address the difficult challenge of adapting deep system structure in the light of socially-constructed patterns of use as well as the objective constraints of component functionality and performance.

Another of our systems that makes the past a resource for the present is the Seamful Game. This explores 'seamful design' (Weiser, 1994b; Chalmers, 2004) that lets people take advantage of characteristics of digital media that we often treat as errors and gaps in media, or 'seams' between media. An early version of the game was outlined in Chalmers (2003), but it has undergone several design iterations since then. This is a game for mobile computers, especially handhelds. It is designed to let players take advantage of the spatial variation in wireless network coverage and GPS positioning, and it draws from the history of system use in order to help them achieve this. An example player's street map with an overlay based on past game play is shown in Figure 2.

The game centres on 'coins' that appear on a street map on each player's computer. In order to gain points, players have to get close to coins, pick up and then get into net coverage before they upload the coins to the game server. Coins often appear in areas where there is no network coverage, or where GPS positioning is poor, and so players have to know where such infrastructure–usually assumed to be ubiquitous and seamless–is strong, weak

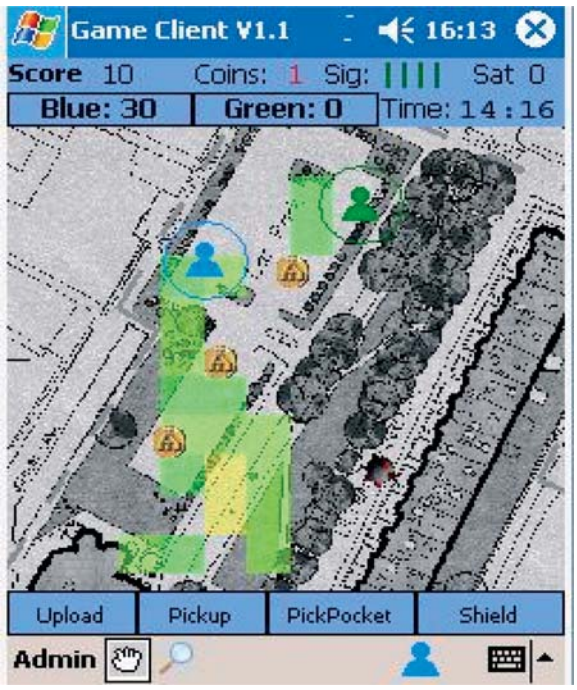

Figure 2. In this mobile game for PDAs, a 'seamful map' of 802.11 signal strength is shown as transparent squares of green and yellow that overlay a monochrome street map. The maps are built up over time from samples gathered during game play, and are made available as a resource for players' system use and development of game tactics.

or missing. A player can take tactical advantage of features such as GPS shadows and gaps in 802.11 coverage, e.g., to avoid or to sneak up on other players. They can use as a resource the history of players' activity: the system periodically samples and logs 802.11 signal strength and the number of GPS satellites, and this collected data is used to dynamically update 'seamful maps' that reflect where players have been, and the infrastructure they used there. Rather like the ESP game (von Ahn, 2004), such games can have useful by-products beyond the game, for example in contributing to shared resources such as PlaceLab (www.placelab.org).

We are also considering other uses of the past as a resource for current users' activity, for example as a means to help users who seem to be in difficulty by showing what other people did in similar circumstances, and as a way to preserve, compare and preview interactions (Lunzer, 1999; Terry, 2004). The past can also be a resource for predictive resource management, as in the MASSIVE CVE's QoS management system (Greenhalgh, 1998) and the web page prefetcher of Signer (2000), and we are exploring ways to make such resource management more apparent and manipulable by users.

In summary, we suggest that by looking deeper into the theory in CSCW and HCI, we can better understand the way that the past is a continually adapting resource for ongoing activity. In our system designs, we can respond to this by selectively making the pattern and detail of past activity part of a system user's current context. Echoing Dourish's guidelines, we suggest that there is useful work to be done in making records of the past into useful and practical elements of tools that display systems' state and configuration, and afford system inspection and adaptation, and negotiation and articulation of activity.

5. Systems combining objective and subjective context

Hermeneutics impresses upon us the significance of individuals' histories as a part of context. Another useful development was the way that hermeneutics began to address the split between objective and subjective. This is relevant to ubicomp and context-aware computing because it can help us see that the incompatibility of the positivist and phenomenological perspectives on context may not be as absolute as Dourish suggested. Applying phenomenological ideas to systems design is difficult, as Dourish and Weiser point out, but it seems inappropriate to accept an intractable dichotomy when contemporary philosophy does not see things quite that way.

If one accepts this broader view of use, coupling and contextualisation, what changes in system design principles can one assume? One issue for ubicomp designers to consider is that long-term use of their system is likely to include focused, rationalising, present-at-hand use: breakdowns, analysis,

reflection and self-presentation. Ideally, we might make a system in which ongoing system execution – including any system adaptation – is so well-coupled with use that its users never have to rationalise about it, focus on it, explain its use to others, or explicitly approve any adaptations. Let us take a pragmatic view of this ideal; it will never happen. However, accepting that users will sometimes focus on and rationalise about a tool should not be taken as a reason or excuse to make a tool that they *always* have to focus on, in order to use it at all. Instead, we suggest that systems support rationalising present-at-hand use in ways that feed into and aid the process of coupling and contextualisation that leads to embodied interaction. We should treat system design that affords episodes of objectification of use and conscious interaction as conforming to the ideals of ubiquitous computing, rather than contrary to them – but only if the effect of those episodes is to make the system better woven into everyday life and embodied interaction.

We can use as a design example Dourish's proposal of an information space for revealing, articulating and adapting system structure and its use. We would expect that one component of such a system would be a manipulable representation of 'objective' system structure, as he suggests. However, other components seem desirable given our perspective on this kind of system. Revealing and articulating everyday activity and embodied interaction suggests that this activity and interaction is recorded, represented and made a resource for times when users focus on the system in a rationalising way.

This is likely to mean more than replaying or listing all the events and actions recorded by the system in full detail, i.e. playback of recordings or logs of activity in a 'raw' state will not, in itself, meet these ideals. Even though the finitude of systems' sensors and representational schemes already abstract over and select from human activity, users are likely to find that the volume of raw data is too high and the relevance of much of it is too low. As mentioned at the end of the last section with regard to the George Square system, one useful form of abstraction may be based on the temporal patterns of past use, such as clustering and correlating tracked features such as locations one has entered, web pages loaded into one's browser, and tools and devices one has used. These would afford, for example, comparing one's recent activity with what others did in similar circumstances. (Of course, one might alternatively enter or select such features to explicitly form a query.) The system could then find or recommend other past occurrences of those actions and interactions, determine who else often went to the same places, looked at the same web pages, used the same tools and devices, and so forth – and then display the record of what people did around that time e.g., what other locations, pages, tools and devices preceded, followed and were combined with each such past use within a given 'window' of time.

A general system design goal we suggest here is to interconnect objective representations of system structure with other more subjective and 'historical'

representations. In each would be tools for abstraction, selection and so forth. For example, class hierarchies and database table structures might possibly be used in the first case, while clusters, selections and time windows might be useful abstractions over past use of the same system. One could concentrate on and interact with particular components or elements of system structure, and the system could highlight in a neighbouring display the patterns of past use of those selected components: where they were used, who used them, and so forth. One could concentrate on and interact with one or more locations or web pages, and have highlighted in a neighbouring display the elements of system structure that were used most often or most problematically in those locations and with that information. Note that focusing on the objective component could trigger the subjective component to act as a 'contextual' display, and vice versa, so that neither is primary: users could use activity in one to feed into the other and then back again.

For example, at Glasgow we are working with histories of system use, often generated by combining user activity logs (e.g., web proxy logs, GPS/location logs from PDAs) and instrumentation of software (e.g., print statements for debugging, system logs of components being loaded and methods being called). We began by building a tool to combine logs from PDAs and the server in the seamful game, and overlaying the street map with data on game events and system log data so as to visualise or 'replay' the game (Figure 3). Depending on the data selected, one can present past games more from a player's perspective or from a system designer's perspective. We are now connecting this 'replayer' to Microsoft's *Visual Studio* IDE (msdn.microsoft.com/vstudio), to form a hybrid system called *InsIDEout*. This tightly links the code browsing and editing, and the selective playback of the game, e.g., seeing where on the map selected debug statements were used, whether the player had net coverage at that time. We wish to show and tightly interlink what users did in game terms (e.g., where they moved, what game events happened) and what users did in infrastructure or system terms (e.g., which components they ran, and where and when selected classes, methods and variables were used or changed).

We are pursuing design that works with the way that the histories and patterns of use of ubicomp systems are important for the programmer in understanding how to change or adapt the code structure, and vice versa: the code structure affects and constrains what histories and patterns of use can arise. This work is intended to blur the boundary between recording and redesign, or between use and reuse of system components. We would like to make the work of debugging and instrumenting more part of the interaction design for users too, so that they can control more of who, where, when and what is logged and analysed – because logging affects system performance, and also is a means of self-presentation to others. Analysis can help players pick up good tactics and see how badly certain others play, and redesign can

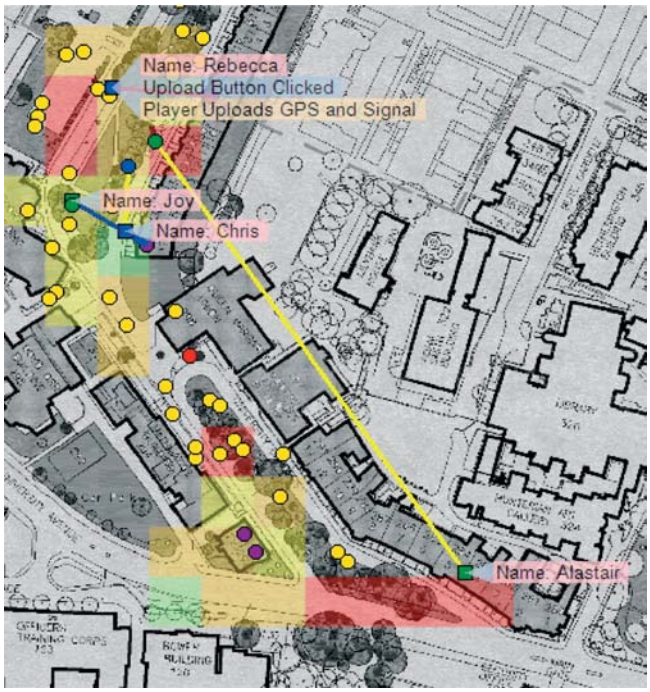

Figure 3. Historical data from PDAs and servers in the Seamful Game is combined in tools to replay game activity, and to link system use to system structure. Players and developers can analyse game tactics and system performance. Replaying often reveals discrepancies between the server's model of activity, and players' activity as tracked via their PDAs. This image shows a player, *Alastair*, whose current GPS position (bottom right) is far from the position shown on players' maps (top left), which is the last the server received. Such differences and delays can be used to advantage by players, and used as a resource for design.

change their tactics and *their* game. By blurring the distinction between system use and system design, we also reflect and support the way that an increasing number of large collaborative systems are designed, redesigned and modified by people who use them, in particular the 'modding' community of game players.

In summary, we suggest a pragmatic design response to the inevitability and importance of present-at-hand use, informed by an understanding of the effect of history in context and contextualisation, and the interdependence of objective and subjective modes of interpretation. We suggest that there are practical ways to support people's interweaving of present-at-hand use and ready-to-hand embodied interaction. Temporal patterns and structure in embodied interaction can feed into and be resources for present-at-hand use. System designs should support people in rationalising, focusing on and abstracting over the system 'in itself' along with its past use, so that people might adapt the system so as to better feed into and be a resource for their

later transparent ready-to-hand use, and with the other people and other media that make up their everyday activity.

6. Conclusion

This paper has examined a number of the ideals and origins of context-aware and ubiquitous computing, looking especially at the effect of the past on one's ongoing activity. One's experience and understanding of different modes of use and heterogeneous media are important resources for one's activity among the people, systems and artifacts currently at hand. This led us to a reassessment of the notion of transparency that has characterised ubiquitous computing, in particular the way that more present-at-hand and 'visible' interaction is essential to the process of a tool or system becoming ready-to-hand, transparent and contextualised within a user's activity. Shifts and transitions between modes of use such as transparency, breakdown, analysis, reflection and self-presentation are not only inevitable but also vital to experience and understanding.

Given such a theoretical standpoint, a number of consequences for system design arise. It seems difficult to accept Weiser's ideal of design for transparency as an achievable ideal. We have to accept that a system occasionally will be, and should be, used in a more ready-to-hand way. We suggest that supporting everyday use means supporting present-at-hand use as well as ready-to-hand use, and making one a resource for the other. In our system work we are exploring ways to couple and connect the systems or system components that handle these different modes of activity, for example by tracking and logging user activity and making it a resource for users and developers. This paper offers examples of how a number of researchers and developers make use of past activity, so that designers and users can understand and adapt system behaviour and their own activity. The paper does not address the issue of the future, for example how future expectations and plans affect ongoing activity and can be resources in a context-aware systems, but we expect to and plan to address this important topic in future work.

Overall, we see significant potential in making more use of the past and the future in context-aware systems design, for example through subsystems such as recommenders, maps of the availability of infrastructure, helpful demonstrations of what people did in similar circumstances to one's own, QoS management, prefetching and system adaptation. We suggest that a historical view of context, that takes account of the interweaving of tools, media, modes of use and people in each individual's experience, activity and interpretation will let us bridge between the apparently incompatible approaches of CSCW and ubicomp. System design that combines and couples

representations of objective structure with patterns of individuals' use appears to be a promising yet practical part of this bridging work. We see this as contributing to a larger goal: design practice and theory that are in accord with each other, and in accord with people's use, interpretation and appropriation of technology.

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