Seeking a Foundation for Context-Aware Computing

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RUNNING HEAD: SEEKING A FOUNDATION

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Brief Authors' Biographies: Paul Dourish is an assistant professor in Information and Computer Science at UC Irvine. His principal research areas are in HCI and Computer-Supported Cooperative Work; his current research involves the design and evaluation of collaborative information infrastructures, and explorations in embodied interaction. His book, *Where the Action Is: The Foundations of Embodied Interaction*, will be published by MIT Press this year.

ABSTRACT

Context-aware computing is generally associated with elements of the Ubiquitous Computing program, and the opportunity to distribute computation and interaction through the environment rather than concentrating it at the desktop computer. However, issues of context have also been important in other areas of HCI research. I argue that the scope of context-based computing should be extended to include not only Ubiquitous Computing, but also recent trends in tangible interfaces as well as work on sociological investigations of the organization of interactive behavior. By taking a view of context-aware computing that integrates these different perspectives, we can begin to understand the foundational relationships that tie them all together, and that provide a framework for understanding the basic principles behind these various forms of embodied interaction. In particular, I point to phenomenology as a basis for the development of a new framework for design and evaluation of context-aware technologies.

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1. INTRODUCTION

As witnessed by the wide range of contributions to this special issue, the topic of context has become a central focus for a considerable number of research investigations around the interaction between humans and computers. There are various potential reasons for this, reflecting the various forms that "context" can take in these different investigations. One spur to the emergence of context-aware computing has been the novel technical opportunities afforded by falling costs, sizes and power requirements for a range of computational devices and associated advances in sensor technology, which jointly allow us to develop new forms of embedded interaction, augmenting physical environments with computation that can be responsive to the needs and activities of the people that occupy them. A second is the recognition of the mutual influence of the physical environment and the human activities that unfold within it, so that aspects of the setting can be used both to disambiguate and to provide specialized computational support for likely action. A third is an increasing understanding on the part of system developers that human activities, including those that we conduct with and through computation, are enmeshed in a variety of practices and relations that make them meaningful by setting a context within which they can be understood and evaluated. A fourth is the influence of design which draws attention to the symbolic as well as the instrumental use of technologies and the roles that each conception of technology need to play in their design and deployment.

However, despite (and perhaps, because of) the wide range of investigations of context-aware computing currently under way, there is very little consensus on precisely what context-aware computing is. In turn, this leads to a somewhat ad hoc approach to both the development and evaluation of technologies that adopt different aspects of the general "context-aware" argument. In this essay, I want to outline a position on the foundations of context-aware computing. In particular, I want to argue that two distinct strands of what we might call context-aware computing within HCI research, although typically conducted and developed in isolation, are in fact two aspects of the same broad program. These two topics are, first, physically-based interaction and augmented environments, and, second, attempts to develop interactive systems around understandings of the generally operative social processes surrounding everyday interaction. By seeing these as fundamentally related topics of investigation, we can identify a set of underlying positions that point towards a foundational model that underlies context-aware computing and can provide a framework by which context-aware systems might be more systematically understood.

I will begin by briefly discussing the two areas of research separately, before going into more detail on how they can be seen to be related.

2. TECHNICAL CONCEPTIONS OF CONTEXT

To the extent that context-aware computing is currently a “hot topic” within the HCI research community, it is primarily a technical concern; that is to say, a range of recent technical advances have made it possible for context-aware computing systems to appear on the scene and to provide a range of potential technical solutions to the problems of fitting computation to the immediate needs, skills and abilities of people engaged in everyday work. For my purposes here, two particular related proposals will serve to characterize the primary positions within this arena – Weiser’s “Ubiquitous Computing” (Weiser, 1991) and Ishii’s “Tangible Bits” (Ishii et al, 1998).

Weiser’s vision of Ubiquitous Computing was founded on two observations. The first was the most successful technologies are those that recede into the background as we use them, becoming an unannounced feature of the world in which we act. This model of technology stands in stark contrast to most interactive computational technologies whose complexity makes them extremely obtrusive elements of our working environments, to the extent that those environments – working practices, organizational processes and physical settings – need to be redesigned to accommodate computation. The second observation was that the relentless downward march of both the price and the size of computational technologies, as described by Moore’s Law, was in the process of making computation small and cheap enough that a new economic and technical model for computation could emerge. Computation can be incorporated into a technical system for a cost of less than a dollar, making it possible to conceive of a situation in which the everyday environment is suffused with low-power, low-cost embedded computation. Weiser saw that these two observations were strongly related, and that the idea of computation embedded into the everyday environment opened up the possibility of computer technology receding into the environment, and become useful to us in completely new ways. When computation was embedded into the environment, computers as we currently know them (boxes on desks) could disappear in favor of an environment in which we could be responsive to our needs and actions through ubiquitously-available computational power. Weiser’s notion of Ubiquitous Computing (or “UbiComp”) has since been the inspiration for a wide range of technical developments, and the model of context-aware computing espoused by the anchor paper in this volume (Dey et al, this issue) follows in this tradition.

Ishii’s “Tangible Bits” agenda is a distinct and more recent development, although it has its origins in aspect of Weiser’s program. Ishii observed that we operate in two different world – the world of computation (“bits”) and the world of physical reality (“atoms”). However, although the world of physical reality is one with which we are deeply and intimately familiar and one in which we are, as organisms, evolved to operate, most interactive systems make very little use of these natural skills and abilities in supporting interaction. The relationship between physical and computational interaction is largely limited to pressing keys and moving mice. Ishii set out to forge a much stronger relationship between the two and, in the process, allow computation to engage with and harness our physical and tactile abilities to support computational tasks. Along with his students, he has developed a wide range of technologies that bridge between the world of atoms and the world of bits, manifesting computational entities as objects and images in the physical world, and using physical interactions as a means of controlling computational entities. Examples include metaDESK, a system for exploring geographical information through the spatial manipulation of proxies for real-world features (Ullmer and Ishii, 1997); Urp, an urban planning system combining physical models of buildings with virtual simulations of shadows, reflections and weather patterns (Underkoffler and Ishii, 1999); and Triangles, a construction kit for multimedia narratives based on a physical construction model (Gorbet et al., 1998).

The Ubiquitous Computing and Tangible Bits programs differ in emphasis – UbiComp tends to explore the relationship between activities and the environment within which they take place, while tangible interfaces rely on the creative use of physical and spatial manipulations to control computational worlds – but they share a number of critical features. First, they both attempt to exploit our natural familiarity with the everyday environment and our highly-developed spatial and physical skills to specialize and control how computation can be used in concert with naturalistic activities. Second, they both use spatial and temporal configurations of elements and activities in the real-world to disambiguate actions and so make computational responses a better fit for the actions in which users are engaged. Third, they both look for opportunities to tie computational and physical activities together in such a way that the computer "withdraws" into the activity, so that users engage directly with the tasks at hand and the distinction between "interface" and "action" is reduced. It is particularly in this third way – the idea that the world *is* the interface – that the Tangible Bits program shows its intellectual ancestry in Weiser's model of Ubiquitous Computing.

These two approaches, and in particular the idea of Ubiquitous Computing, are the technical directions most closely associated with the idea of context-aware computing, as can be seen from the tenor of a number of articles included in this volume, especially Dey, Abowd and Salber's anchor paper. However, I want to argue here that a second area of recent investigation in HCI also constitutes a form of context-aware computing, and that in fact that the connections between the two go much deeper than simply a superficial concern with the notion of context. The second area is the broad set of investigations into the relationship between interactions between people and technology and the social settings in which they unfold.

2. CONTEXT IN SOCIAL ANALYSIS

The origins of HCI lie in the formation of an interdisciplinary endeavor combining cognitive psychology with computer science. Since that time, the scope of HCI has continued to broaden as newer perspectives have been introduced. As we have turned our attention to topics such as Computer-Supported Cooperative Work, and the organizational roles and consequences of information technology, social sciences have become increasingly relevant.

The question of context is central to social analyses of interaction, in two ways. The first is the fairly straight-forward observation that social analyses look beyond simply the interaction between an individual user and a computer system. They look at the context in which that interaction emerges – the social, cultural and organizational factors that affect interaction, and on which the user will draw in making decisions about actions to take and in interpreting the system's response. So, sociological perspectives have pointed out that instances of interaction between people and systems are themselves features of broader social settings, and those settings are critical to any analysis of interaction. This is what Grudin (1990) characterized as "the computer reaching out" as the context of interaction gradually expands to include an larger and larger frame of reference.

However, the idea of context is also plays a more fundamental role in forms of social analysis common in HCI research. One of the most influential books to introduce sociological reasoning to problems of interaction was Lucy Suchman's *Plans and Situated Actions* (Suchman, 1987). Suchman drew on ethnomethodology (Garfinkel, 1967), an analytic approach to the organization of social action, to provide a forceful critique of the then-dominant formal planning model in Artificial Intelligence. Ethnnomethodology is an approach to social analysis which explains the orderliness of social conduct not in terms of abstract theories, but rather as the practical achievement of members continually working to render the world sensible and interpretable in the course of their everyday actions. Critically, this means that, for ethnomethodology, social conduct is an improvised affair, carried on in real-time in the course of everyday activity. Social conduct is orderly not because it is governed by some overarching theoretical construction, but because people make it orderly. Ethnomethodologists argue that people find, within the conduct of everyday affairs, the resources by which those affairs can be found to be meaningful and rational; and so in turn, they recommend that the investigation of social order should not take the form of a search for theoretical principles, but rather should involve the careful examination of specific instances of organized action, so as to be able to uncover the means by which people *produced* the rationality that they exhibit.

Drawing on an ethnomethodological foundation, Suchman used materials from experimental investigations of copier use to show that people's interactions with technology exhibited this moment-by-moment, improvised character. This perspective, in which the sequential organization of conduct arises in response to the immediate circumstances in which it arises, Suchman terms the "situated action" perspective, and stands in contrast to the traditional planning model in which the sequential organization of action is predetermined by an algorithmic exploration of the "search space" of goals and actions. Suchman does not reject the notion of "plans"; instead, she observes that plans, as prespecified formulations of future action, are merely one of a number of possible resources that people draw upon in answering the question, "what do I do next?"

This perspective suggests a deeper role for context in interaction. It argues that the context in which actions take place is what allows people to find it meaningful. Context – the organizational and cultural context as much as the physical context – plays a critical role in shaping action, and also in providing people with the means to interpret and understand action. Similarly, since the meaning of action is interactionally determined, temporal context is also involved, as actions and utterances gain their meaning and intelligibility from the way in which they figure as part of a larger pattern of activity.

3. EMBODIMENT

From the preceding sections, we can see that the role of context in interaction extends beyond simply the sort of spatial and temporal context that lies at the heart of the Ubiquitous Computing vision, and more recent articulations of it such as that of Dey and his colleagues. Beyond this, we need also take account of social, cultural, organizational and interactional context, which are equally telling for the ways in which action will emerge. (Of course, these are not independent of each other. See Agre's contribution to this issue for an exploration of the ways in which spatial arrangements are often reflections of institutional arrangements.)

I want to argue, though, that these two areas of research, with their common concern with context, are more than simply related to each other, but in fact are two different strands of the same program of investigation. It is not the central role of context in each that unites them as a common program, but rather their mutual dependence on the concept of *embodiment*.

By embodiment, in this context, I mean not simply physical presence, although that is certainly one relevant facet. More generally, however, by embodiment I mean a presence and participation in the world, real-time and real-space, here and now. Embodiment denotes a participative status, the presence and occurrentness of a phenomenon in the world. So, physical objects are certainly embodied, but so are conversations and actions. They are things that unfold in the world, and whose fundamental nature depends on their properties as features of the world rather than as abstractions. So, for example, conversations are embodied phenomena because their structure and orderliness derives from the way in which they are enacted by participants in real-time and under the immediate constraints of the environment in which they unfold.

Weiser's program has embodiment at its heart. The essence of Ubiquitous Computing is the idea of the computer withdrawing into the background, and so supporting a form of interaction with computation in the form of embodied physical interaction rather than manipulating abstract representations in a computer system. By the same token, Suchman's situated action approach is also founded on the concept of embodiment. In common with the general views of ethnomethodology, Suchman rejects abstract depictions of action and argues instead that we must see the orderliness of action as derived "bottom-up" from the local, situated activities of actors. This model places the real-time, real-space activities of social actors – embodied actions – before abstractions or theoretical accounts of them. Practice precedes theory.

Embodiment, then, is the key idea that ties together these two programs of work and reveals them as aspects of a single line of investigation. However, I have another reason for pointing to embodiment, in particular, as the key relationship between the two. It is that embodiment is not a new idea, but rather has been at the center of one branch of philosophy for the last hundred years or so. That is phenomenology, which, loosely, is the philosophy of the phenomena of experience. The reason that it is particularly interesting to observe that the concept of embodiment has this sort of history is that it opens up the possibility that, by understanding and drawing on that history, we might be able to develop a foundational understanding of embodied interaction. Such a foundation could do two things. First, it could provide a way to relate the experience of embodied interaction in the social domain to the technical, and vice versa; and second, it can provide a stronger basis on which embodied interaction technologies can be designed, evaluated and analyzed.

4. PHENOMENOLOGY

There is no opportunity, in the space afforded by this essay, to detail the phenomenological position in anything other than the broadest strokes.[1] So, here, I will attempt only to give a flavor of the position and show how it might hold some promise for an investigation of embodied interaction.

Phenomenology, as a philosophical position, was originally developed by Edmund Husserl. Husserl, who had trained as a mathematician, was concerned with what he saw as a "crisis" for science, in which it was becoming increasingly distant from practical human concerns – the very practical concerns that had spurred the development of mathematics and science in the first instance. The domain of science and mathematics was increasingly, he felt, an abstract and idealized realm of dimensionless points and frictionless surfaces which had supplanted the real world of lived experience where practical concerns were worked out. His goal was to reconnect science with the real world, and the means by which this was to be done was to develop the philosophy of human experience on a rigorous scientific footing. This philosophy of the phenomena of experience was phenomenology. Phenomenology set out to explore how people experience the world – how we progress from sense-impressions of the world to understandings and meanings. Fundamentally, it put primary emphasis on the everyday experience of people living and acting in the world, and the "natural attitude" towards the world that lets them easily and unnoticeably make sense of their experience.

Husserl's phenomenology was considerably developed and revised by perhaps his best-known student, Martin Heidegger. Heidegger is the major figure associated with twentieth-century phenomenology, but his work is based on a rejection of one of Husserl's basic premises. This is the doctrine of Cartesian dualism – the idea, descended from Descartes, of the separation of mind and body. Husserl, who saw himself developing a Cartesianism for the modern age, had adopted this position, and his form of phenomenology explored the inner mental phenomena by which sensory impressions could be interpreted and meaning assigned to them. Heidegger rejected this idea. He argued that rather than assigning meaning to the world as we perceive it, we act in a world that is already filled with meaning. The world has meaning in how it is physically organized in relationship to our physical abilities, and in how it reflects a history of social practice. For Heidegger, the primary question is not "how do we assign meaning to our perceptions of the world?" but rather, "how does the meaning of the world reveal itself to us through our actions within it?"

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[1] Interested readers are referred to Dourish (2001) for more information.

The most important feature of how we encounter the world, from Heidegger's point of view, is that we encounter it *practically*. We encounter the world as a place within which we act. It is through our actions in the world – through the ways in which we move through the world, react to it, turn it to our needs, and engage with it to solve problems – that the meaning that the world has for us is revealed. So, for Heidegger, action precedes theory; the way we act in the world is logically prior to the way we understand it.

Heidegger's phenomenology is somewhat familiar in HCI through the work of Terry Winograd and Fernando Flores, and their explorations of technology in use (Winograd and Flores, 1986). My goal here, though, is slightly different. Certainly, the distinction that they point out, between technology "present-at-hand" (visible and available within the environment) and "ready-to-hand" (so seamlessly integrated into my activities that it is "withdrawn" into the activities in which I am engaged), is directly relevant to the Ubiquitous Computing position. However, I want to point out two other relevant facets of Heidegger's proposal. The first is the primacy of action in the world, and the second is the central importance of meaning in Heidegger's analysis. Taken together, these point to the fact that meaning, for us, arises from the ways in which we engage with and act within the world. I believe that this is of central importance in trying to understand the notion of embodied interaction that lies at the heart of the two aspects of context-based computation discussed earlier and elsewhere in this issue.

Before closing this discussion of phenomenology, I want to briefly discuss one other strand of work which plays an important role in tying phenomenology to context-based computing in HCI. This is the work of Alfred Schutz, and the application of phenomenological ideas to the social world.

Like Heidegger, Schutz had studied with Husserl. Schutz's major contribution was to combine Husserl's phenomenology with Weber's work on social interaction. As described above, Husserl had been concerned with how we experience the world around us and find it meaningful. Schutz extended this to incorporate the problem of intersubjectivity – that is, how two people, who have access only to their own thoughts and immediate experiences, can nonetheless come to find each other's actions meaningful, and can established shared meaning and common understandings. Schutz saw the problem of intersubjectivity as one that characterized the "natural attitude" that Husserl had described, and took Husserl's concept of the *lebenswelt* or life-world, the world of daily lived experience, as the place where the problem was worked out. He proposed an approach to intersubjectivity rooted in our common experience of the world and on the way in which we can interpret and understand the actions and motivations of others by appeal to the assumption of a shared life-world that, first, grounds our common experience and, second, gives me the necessary background to understand your actions as being rational.

The immediate relevance of Schutz's work for the perspectives that have been applied to problems in HCI is that it was an important inspiration for Garfinkel's development of ethnomethodology which in turn has come to occupy an important role in contemporary HCI research. Garfinkel's project clearly reflects Schutz's conception of intersubjectivity as first and foremost a practical problem to be solved by members in the course of their ongoing interactions, and Garfinkel acknowledges the important role that Schutz's work played in his thinking. So, while Heidegger's conception of the role of technology in action clearly links phenomenological thought to the sorts of context-aware computing incorporated into the Ubiquitous Computing program, Schutz's work plays a complementary role for the sociologically-based explorations of context and interaction.

5. CONSEQUENCES AND CONCLUSIONS

So what does this all add up to? What can it tell us about context-aware computing?

Let me briefly summarize my argument so far. I have argued, first, that the importance of context-based computing extends beyond simply those systems that are designed around an awareness of spatial location, of user identity, of the proximity of people and devices, and so on, but that it is also a critical feature of sociologically-motivated explorations of interaction. Second, I have attempted to show that these two areas of context-based exploration are not simply related to each other, but in fact are aspects of the same program due to the common foundations that they share. Third, I have argued that this common foundation is the notion of "embodiment", as it has been developed in phenomenological philosophy. Fourth, I have proposed that, by exploring how the notion of embodiment has featured in phenomenology, we can uncover a conceptual framework that helps us to better understand embodied interaction. So the question at this point is, what does phenomenology tell us about context-based computing? In the interests of space, I will restrict myself to two particular observations here.

Embodiment is about establishing meaning. The first thing that we can observe on the basis of the phenomenological position is that embodiment is about meaning. We might be inclined to imagine that embodied approaches to interactive systems are successful because they are more familiar to us, or that they capitalize on natural social or physical skills. Indeed, these might be true on a superficial level. However, phenomenology turns our attention to how we encounter the world as meaningful through our active and engaged participation in it, and so we can see that the underlying purpose of this sort of "more natural" approach to interface design is that it allows us to engage with technology in a different way – in ways that allow us to uncover, explore and develop the meaning of the use of the technology as it is incorporated into practice. As a design concern, then, this places limits on how we think about applying social and physical interaction models to interactive systems. The design concern is not simply what kinds of physical skills, say, we might be able to capitalize upon in a tangible interface, or what sorts of contextual factors we can detect and encode into a ubiquitous computing model. Instead, we need to be able to consider how those skills or factors contribute to the meaningfulness of actions. In the case of ubiquitous computing applications, for example, that might mean focusing on "place" rather than "space", since it is a notion of "place" that is socially meaningful (Harrison and Dourish, 1996); while in a socially-organised application, it might mean looking at how the abstractions that the interface presents make themselves available to processes of examination and interpretation (Dourish and Button, 1998).

Meaning arises in the course of action. The second observation that we are led to by studying the phenomenological work is that the meaning of a technology is not inherent in the technology, but arises from how that technology is used. Meaning is something that comes about through an encounter with the technology (or with other people), and so arises from the interaction between the parties. The significance of this for design is that, in designing interactive systems, we typically take the meaning of the elements of the system – its components, processes and representations – to be given or static within the frame of the application. What an action in the interface "means" is something that we typically imagine to be determined by the designer. However, the notion of meaning as being interactionally determined means that we have to see this in a different light. What a user means by engaging in some action – by recording or communicating information through a system, by incorporating the system into their working practice, and so forth – may have little to do with what the designer had imagined. Most importantly, the designer does not have absolute control, only influence. In turn, this suggests that, if the meaning of the use of the technology is, first, in flux and, second, something that is worked out again and again in each setting, then the technology needs to be able to support this sort of repurposing, and needs to be able to support the communication of meaning through it, within a community of practice.

So, the phenomenological background to the ideas of embodied interaction, as they work themselves out in both the domains of ubiquitous computing and social studies of HCI, cast light on a set of underlying concerns that are different than those we might see if we looked at them individually. In addition, it begins to show more concretely how these two novel approaches to interaction have more than simply a shared interest in "context" at their heart. Finally, it offers the opportunity to build a more comprehensive framework that can help to articulate what makes context-based computing important and effective, and how to both design and evaluate technologies that take advantage of it.

NOTES

Background. The material outlined in this essay is explored in greater detail in a forthcoming book (Dourish, 2001).

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FOOTNOTES

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