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Embodied Interaction: Exploring the Foundations of a New Approach to HCI

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Abstract

As we move towards the close of the millennium, it is perhaps not surprising that we take the "long view" and attempt to find, in the history of HCI, clues to its future. In that vein, this article focuses on the theoretical and foundational underpinnings of interactive system design and development. Drawing upon recent trends in interactive systems research, it proposes "embodiment" as the basis for a new foundational approach to HCI. Embodiment reflects both a physical presence in the world and a social embedding in a web of practices and purposes. After a review of the role that embodiment has played in philosophies of presence and action through the twentieth century, the outline of a new foundation for the design and analysis of interactive systems is presented.

1 INTRODUCTION

Millennial fever is upon us. Against a background of debates over when the new millennium *actually starts*, discussions are held in the media and over dinner about how the progress of the last thousand years can be projected into the next. Lists are drawn up of the most important human contributions of the last thousand years. What was the most powerful idea? The most noteworthy invention? The most significant discovery? What does the future hold, and how will we chart a course through it?

On reflection, it is perhaps not surprising that academic circles should host the same sorts of discussions. On the other hand, this poses a serious problem for HCI. Computer Science, as a discipline, is scarcely sixty years old; HCI, perhaps, thirty. It is hard to hold up the mouse as the most significant invention of the millennium when its competition includes the longbow, anaesthesia, the telescope and the scientific method. We have similar problems when trying to predict the future course of events. It doesn't take a statistician to see that thirty years of data does not support extrapolation to one thousand.

However, all is not lost; it rarely is. This issue contains a variety of assessments of the state of HCI as we approach the new millennium, and predictions of how we might make the transition. This article is such an exploration: an attempt to synthesise some recent developments in the HCI research and to project them into future directions. Since the tone of this issue is more reflective, however, this article is less concerned with design and the specifics of the interfaces we might expect to encounter once the Y2K bug has become a thing of the past, and more concerned with the conceptual foundations for a new model of interaction that recent trends are beginning to show.

The fundamental notion that underpins the approach this article outlines is *embodiment*. What I mean by embodiment, in detail, is best worked out in the course of a tour through recent developments and the foundational backdrop against which they have played out. At a high level, though, embodiment is the property of being manifest in and as a part of the world. A variety of recent developments have begun to take on embodiment as a fundamental feature of interaction, rather than as a side-effect of interactive system development. In beginning to accept embodiment as a central feature of how we think about interaction, HCI has not been ploughing new ground. Embodiment, in a variety of forms, has been a critical component of phenomenological thought throughout the twentieth century. It is to this philosophical approach that we will turn to look for guidance in formulating new foundation for interaction and interactive systems.

First, though, we will consider how it is that we came to this point. As with any exploration of the future, we first need a good understanding of the past and the present. The next section will briefly reconsider the development of HCI as a field, with a particular emphasis on the varieties of human expertise it has capitalised upon. Then, we will consider two recent steps in HCI's progress: *social computing* and *tangible computing*. These two explorations set the scene for the foundational exploration that is the primary focus of this article. From those, we will go on to consider embodiment as a fundamental and unifying principle.

2 HCI AND HUMAN SKILL

The history of HCI can, in many ways, be seen as an ongoing attempt to capitalise on the full range of human skills and abilities. These are not the skills we acquire from training and careful practice, but rather those everyday, natural abilities that most of us take for granted; picking up a ball, not juggling with it.

The earliest computers were dedicated machines, whose programs were encoded in their wiring. Interacting with the computer meant rewiring it to configure it for a new task. Output generally took the form of patterns of flashing lights. With the advent of stored program computers, and of batch processing, interaction with machines typically took form of punched cards and line printer output. Interaction become symbolic rather than electrical.

The advent of time-sharing was also the advent of interactive computation. Early command line interfaces took advantage of our ability to process symbolic information, and to work with words and numbers. Interaction became textual and language-based, taking advantage of our ability to deal with words, sentences and grammar.

The next stage, and perhaps what we commonly think of as the genesis of the modern interface was the advent of visual computing, demonstrated most vividly by the systems developed at Xerox PARC, first the Alto (Thacker et al., 1982) and then its commercial successor, the Star (Smith et al., 1982). The SmallTalk system running on the Alto hardware featured a mouse tightly coupled to an on-screen cursor, used for pointing, selecting and dragging; a high resolution bitmapped display presenting graphics along with multiple text faces; overlapping windows; pop-up menus; and other elements that have persisted with only minor changes right through to the laptop computer on which

I am currently writing this article. This approach exploited a whole new range of human skills. Visual perception was integral to the interface in a much deeper way than had been true at earlier stages. Now it relied not just on the ability to see characters, but to recognise visual patterns, and to visualise the world of overlapping windows. Now, too, using the mouse relied on our ability to see the moving cursor on the screen as an extension of the hand; and on our ability to discern causal relationships between events, so that the movement of objects on the screen could be seen as being causally related to human-initiated action. A whole new range of opportunities were opened up by the new skills and abilities that the new interfaces could capitalise upon.

The new level of interaction that these mechanisms afforded has remained, for a long time, the basis for much of what we still do at computers. The computer of today looks much like those developed at PARC; while modern computers may be smaller, faster, sleeker and more powerful, their basic interaction models have changed very little. However, other developments have promised new models of interaction. Perhaps the most significant in recent years have been the development of virtual reality and augmented reality systems. Immersive Virtual Reality technologies create virtual worlds rendered in three dimensions, and then present them to the user as if they were real, complete with stereoscopic displays and movement in the virtual space correlated with the user's own movement. Proponents of virtual reality technology emphasise the ease of use that virtual reality systems provide through their mimicking of reality, allowing users to transfer familiar skills from the real world to the virtual.

Newer developments can also be seen as attempt to harness other areas of human skill, experience and ability and so ease the interaction with computer systems. I want to focus on two areas in particular. The first of these, social computing, attempts to capitalise upon social skills and aspects of the social setting in which systems are used. The second, tangible computing, is exploring ways to exploit our physical and tactile skills.

3 SOCIAL COMPUTING

Another way to see how HCI has gradually attempted to capitalise upon different aspects of human skill and experience is to see the way in which it has forged a variety of disciplinary partnerships in the course of its history. In the earliest days, before HCI had emerged as a discipline, it was computer scientists, mathematicians and engineers who were the sole developers of mechanisms for interaction with technology. Subsequently, HCI, as a delineable area of study and research endeavour, arose not least through the fusion of computational techniques with psychological principles, which explored the cognitive demands of interactive techniques and provided new ways to understand, design, measure and evaluate interfaces.

More recently, and in particular since the late 1980's, HCI has been increasingly influenced not just by psychology, but also by sociology. There has been a growing recognition that the activity of the user sitting at a computer is not defined simply by the patterns of their immediate interactions, but by web of surrounding relationships, practices and activities in which they are each embedded. HCI has drawn on a variety of analytical techniques from sociology as a way to understand this aspect of interaction with technology.

One of the most obvious area of application has been in the development of the sub-field of Computer-Supported Cooperative Work (CSCW). CSCW's inherent interest in the work of groups rather than (or, as a context for) individuals meant that it was, naturally, interested in the use of sociological approaches to study collaborative and organisational behaviour. There have been two primary domains for the uptake of ideas from sociology: methods and theory.

By sociological methods, I mean sociological forms of practical enquiry into the work of individuals and groups. By and large, the dominant (although certainly not exclusive) method adopted in CSCW has been ethnography (e.g. Hughes et al., 1993). Ethnography has its origins in the anthropological studies of distant lands and peoples; in contrast to the "armchair anthropology" of the Imperial expansion period of European history, ethnography exhorted its practitioners to go and see, surround themselves with and immerse themselves in the cultural practices they sought to study. It emphasised "the member's point of view", seeking to understand not just what people did, but what they *experienced* in the doing. In the period following the Second World War, ethnographic techniques were adopted by sociologists engaged in a sort of "urban anthropology", looking on twentieth century western living with the skeptical eye of the "professional stranger." The Chicago School of sociological investigation used ethnographic techniques to study Western phenomena such as the lives of jazz musicians, medical students and drug users with the same sort of approach that had previously been applied to studies of Polynesian gift-giving rituals and Amazonian kinship practices.

The primary use of ethnography in CSCW and HCI has been as an approach to field work, and hence, as a tool for gathering requirements for system design. However, as Anderson (1991) has observed, this is to misconstrue what ethnography is. Ethnography is not simply a way of going to field sites and observing what is there; it is also an analytic stance on the data. It is not atheoretic, although its use in HCI sometimes suggests that it might be, or that it is regarded as such.

Since HCI is an essentially practical discipline, it is perhaps not surprising that the adoption of sociological ideas has focussed primarily on the practical techniques that sociology might have to offer. However, there have also been a number of more theoretical relationships forged between sociology and HCI.

The most common of these have employed sociological theory in the analysis of interaction and the use of interactive tools. For example, Suchman's (1987) seminal investigation of interaction problems arising in the use of technology was based on an analytic perspective on social action called ethnomethodology. Suchman's goal was not simply to use her observations as the basis for the design of better devices; rather, her goal was to use these as illustrative materials for a theoretically-founded critique of the then-dominant "planning" paradigm in HCI and AI.

Ethnomethodology, the analytic perspective on which Suchman's analysis was built, has had a significant influence in HCI; out of proportion, in many ways, to its considerably smaller degree of uptake in sociology proper. In CSCW, in particular, ethnomethodology has been a common approach to the study of collaboration; and Conversation Analysis, a branch of ethnomethodology, has been used to explore the nature of human/machine "dialogues" (Frolich and Luff, 1990).[1]

Ethnomethodology is an approach to understanding social action that centrally explores the practical reasoning by which individuals engage in concerted activity; that is, it is primarily concerned the "ethno-methods" by which action is organised and interpreted. In contrast with other, conven-

1. Some possible reasons for this situation are explored elsewhere (Dourish and Button, 1999).

tional approaches to sociology, which are organised in terms of abstractions such as social stratification, roles, convergence or alienation, ethnomethodology regards the detail of practical social action and everyday sociological reasoning as the primary material for study. Ethnomethodology's founder, Harold Garfinkel, has observed that while conventional sociology presupposes the "objective reality of social facts" and proceeds on that basis, ethnomethodology takes the objective reality of social facts as the phenomenon to be studied (Garfinkel, 1991). In so doing, then, ethnomethodology questions the very theoretical and methodological assumptions on which conventional sociology is based.

The basis on which ethnomethodology seeks to respecify the objectives of sociology is also the basis on which it lends itself to the practical goals of HCI. Ethnomethodology's focus on the actual practices of people engaged in real-world activity, and its analytic concern with *what people actually do*, allow it to be adopted by HCI as a discipline with an abiding interest in what people actually do, with an eye to helping them do it better.

However, ethnomethodology has certainly not been the only analytical approach to sociology that has been applied to the analysis of interactive and collaborative work in HCI. For example, Orlikowski (1993; 1996) based her analyses of the use of Lotus Notes on Giddens' "structuration theory" (Giddens, 1984). In particular, Giddens' approach can be used to analyse how users manipulate technologies in specific contexts of use to accomplish their work and how, in turn, their actions draw upon, change and reproduce the social contexts within which they work. Others have turned to approaches such as Activity Theory (Nardi, 1996), Actor Network Theory (Berg, 1997), or Symbolic Interactionism (Star, 1996).

So, a variety of sociological techniques and analytic perspectives have been applied to the domain of HCI. However, these efforts have largely been directed at the analysis of interaction, or the search for requirements for the use of technology in particular work settings. Deeper forms of "social computing" have also been developed, that seek to use sociological analysis as a groundwork for design practice.

For example, Fitzpatrick (1998) use Anselm Strauss' theory of action (Strauss, 1993) as the basis for the Locales Framework, which in turn provides a theoretical motivation for the design of the Orbit collaboration environment (Mansfield et al., 1997). Strauss' theory of action articulates common threads from a wide range of ethnographic investigations and constructs from them a generalised theory of social action, organised around the concepts of actions, interactions, trajectories and social worlds. Fitzpatrick takes the fundamental elements of Strauss' analysis, and in particular his focus on social worlds, as the basis of an analytic model of CSCW. A social world arises from the collective and coordinated action of a group of individuals, and combines actions with the sites where those actions take place and the technology with which they are carried out. Fitzpatrick combines sites and technologies as "locales", or socially-constructed places for the practical accomplishment of work. The Locales Framework provides a richer means to analyse the relationships between the interactional requirements of a social world and the technologies that it brings to bear to meet them. At the same time, it also provides a path for technological development to evolve in concert with those same interactional requirements, by explicitly articulating the relationships between individuals, social worlds, sites and technologies in play in collaborative settings.

Again, seeking to find a deeper connection between sociological investigation and the development of interactive systems, Dourish and Button (1999) explore the relationship between system design and ethnomethodology. In particular, they focus on "foundational relationships", based on the analytic features of each discipline, rather than on opportunistic practical relationships (such as the characteristic role of ethnography as requirements capture). As an example, they draw parallels between the analytic role of "abstraction" for system development, and that of "accountability" for ethnomethodology. In ethnomethodology, accountability refers to the way that human social action is organised in such a way that it can be interpreted, by others, as the sort of action it is. For example, ordinary talk is organised so that it displays its ordinariness in ways that others can interpret, while a greeting is crafted in such a way that it will be interpreted as a greeting, through its organisation as a feature of an interaction (such as when and how it is uttered). Action is accountable in the sense that it is "observable-and-reportable, i.e., available to members as situated practices of looking-and-telling" (Garfinkel, 1967). Dourish and Button explore computational abstractions in the same light, and suggest that one source of interactional problems in HCI lies in the way that computational abstractions are black boxes, in which the activity they encapsulate is obscured from view, and so unavailable to users as a resource around which they might be able to organise their action. On this basis, they present a reconstruction of the notion of computational abstraction designed for the selective inspection of the behaviour that lies behind it.

The uptake of sociological methods has, generally, been more common than the uptake of sociological theory. However, both have had their influence on the development of HCI. They have heightened an awareness and understanding of the context that surrounds activity at the interface. In particular, they have highlighted the fact that interaction takes place within an unfolding pattern of purposeful activity, and that this setting is not only relevant to the activity, but makes it meaningful. The issue of meaning is one that will occupy us again shortly.

4 TANGIBLE COMPUTING

Sociology became a significant feature of HCI investigations mainly with the development of the field of CSCW in the middle to late 1980s. The trend to which we will now turn our attention, tangible computing, is a a phenomenon of the middle 1990s.

It can trace its origins back before that, though. Much of the activity that has now crystallised around tangible computing was based in a vision of "ubiquitous computing", first put forward by Weiser (1989). Weiser was concerned with the dominance of the "boxes on desks" paradigm for interactive computing. Computers, he argued, were tools for doing things (writing books, playing games, talking to people, discussing ideas, or whatever). However, the role of the computer in this process had been reified more than that of other tools we use. Why do we talk of "computer literacy" and "computer skills", but not "lightswitch literacy" or "vending machine skills"? Why do we need to talk about "human-computer interfaces" at all, when we don't need journals and conferences devoted to the design of interaction with door knobs, heating systems or microwave ovens? Weiser's vision, which he dubbed "Ubiquitous Computing", was one in which the traditional desktop computer was no longer the focus of computational interaction. Instead, Weiser postulated the embedding of computation in other objects and devices. Just as a microwave oven contains a microprocessor to manage the computational aspects of microwave cooking, so we could also embed computation in pens, in walls and doors, in notepads and so on.

This was not simply a vision of a possible future, or a set of predictions about the future course of computer system development. It was also a research agenda which Weiser and his colleagues in the Computer Science Lab at PARC set about executing (Weiser, 1993). They developed a range of technologies, such as the Liveboard (Elrod et al., 1992) and the PARCTab (Want et al., 1995), to explore the implications of ubiquitous computing both for users and for system developers.

The emphasis that the Ubiquitous Computing work placed upon computation embedded in the physical world and used to bridge between physical and virtual domains has been, perhaps, the most long-lasting impact of this work, and it is the one that shall concern us here. It gave rise to a series of explorations of interactive technology based on physical interaction. Wellner (1993), for example, developed the Digital Desk, in which, through the use of a video camera and projector, a physical desktop could be used for the manipulation of both physical and digital documents. Fitzmaurice et al. (1995) extended these ideas by introducing the use of physical objects which stand for elements of the computational world and translate physical manipulations into digital ones.

Ishii continued with these explorations at the MIT Media Lab. In his earlier work, he had used video overlay technology to build CSCW patterns supporting both physical and virtual interaction (Ishii, 1990). Following on from his work with Buxton and Fitzmaurice, he developed these ideas into the "Tangible Bits" research program at MIT. Ishii and his colleagues have, through a variety of prototypes, begun a wide-ranging investigation into forms of coupling between the physical and virtual worlds. Examples include Triangles (Gorbet et al., 1998), a "digital manipulative" which uses physical coupling between objects to control multimedia narratives, and the Ambient Room (Wisneski et al., 1998), a personal work space that explores the use of "ambient displays" to give the occupant a sense of both physical and virtual activity around them.

Perhaps the best developed example of this approach that the MIT group has developed is the metaDESK (Ullmer and Ishii, 1997). The metaDESK allows a user to explore an electronic information space (in the case of their primary example, a geographical information system) through a variety of physical manipulations. For example, by manipulating "physical icons" representing particular geographical locations, a virtual map can be scaled, translated and rotated in real time; while a passive lens is instrumented to report its location so that it can be used to indicate regions to be explored in more detail (in a manner similar to the "magic lenses" of Bier et al. (1993), translated into the physical world).

Explorations in tangible computing have attempted to capitalise on a new range of skills, the tactile and physical skills that we employ in dealing with the world around us. Research into tangible computing has taken a step back and realised that, while we currently interact with computers *through* physical objects (such as keyboards, mice and displays), we can better exploit our natural skills if we focus on interacting with the physical objects themselves. The physical objects no longer stand as proxies for purely computational entities like cursors and insertion points, but can begin to take on a more direct role in the interaction. We will come back, later, to look at this issue of directness further. First, though, we will consider the wider issues at work in both social and tangible computing.

5 EMBODIMENT

So far, then, we have examined two recent elements of research into the analysis and design of interactive systems. Social computing arose in the 1980s, and tangible computing in the 1990s. Both are active elements of HCI research that challenge the status quo in the same way as did the graphical user interface and the advent of visual computing in the 1970s. Also like those earlier development, these new approaches attempt to capitalise on different arenas of natural human skill.

Research into these two domains has largely, however, been conducted independently. After all, they appear, on first sight, to be focussed on different problems and different sorts of skills. However, this article is based on the thesis that both of these lines of development—social computing and tangible computing—are based on the same idea, that of *embodiment*. This notion is a common theme running through a good deal of twentieth century thought, and in particular the phenomenological tradition. My argument here, then, is that by looking towards that tradition, we can find the elements of a position from which to understand what is "going on" with these new elements of HCI, and from which to develop them.

What do I mean by embodiment? Embodiment is the property of being manifest in and of the everyday world. Embodiment constitutes the transition from the realm of ideas to the realm of everyday experience. This does not simply imply *physical* embodiment, the embodiment of desks, trees and highways, although that it perhaps the most familiar aspect of embodiment; it also extends to other aspects of our everyday world. Conversation, for example, is embodied, in more ways than simply that speech patterns are carried as physical disruptions in the air. It is embodied in the way that it happens in the world, through the engaged participation of two equally embodied people, and against a backdrop of an equally embodied set of relationships, actions, assessments and understandings. This background *situates* the activity of the conversation. The setting within which the activity unfolds is not merely background, but a fundamental and constitutive component of the activity that takes place.

Embodiment, then, denotes not physical reality but participative status. When I talk of "embodied interaction", I mean that interaction is an embodied phenomenon. It happens in the world, and that world (a physical world and a social world) lends form, substance and meaning to the interaction. Like the example of a conversation, interaction is embodied not merely in the fact that there is physical contact between real fingers and a solid, three dimensional mouse; it is embodied in the sense that its occasion within a setting and a set of specific circumstances gives it meaning and value. By implication, it loses both if removed from those circumstances again.

It is not too hard to see how tangible computing is built upon a notion of embodiment. The tangible computing work attempts to capitalise on our physical skills and our familiarity with real world objects. It also tries to make computation manifest to us in the world in the same way as we encounter other phenomena, both as a way of making computation fit more naturally with the everyday world and as a way of enriching our experiences with the physical. It is slightly harder, perhaps, to see that the trends in what was earlier called social computing are also built upon a notion of embodiment. The use of sociological approaches in the design of interactive technology has, however, been driven primarily by concerns with the interaction of computation and "the workaday world" (Moran and Anderson, 1990). The paradigmatic perspective on social action motivating this approach is the "situated" perspective (e.g. Suchman 1987; Clancey, 1997) which is grounded in the relationship between social action and the settings in which it unfolds, the relationship of embodiment. Least obvious of all is to see that these are, in fact, the *same* notion of embodiment that underwrites both of these lines of investigation. The best way to illustrate that they are is to consider the origin of the notion as it has developed in the body of phenomenological thought through the past hundred years.

5.1 The Phenomenological Backdrop

Phenomenology, as a modern philosophical enterprise, originated in the work of Edmund Husserl. Husserl was a mathematician, and his concern was with the foundations of mathematics and number, which he sought in the ground of human experience of the world. Husserl argued that everyday experience is of concrete phenomena, and it is from such experience and phenomena that our conception of number and of mathematics exists. Phenomenology, then, was based in the phenomena of human experience, in contrast to the abstract entities at the heart of scientific and mathematical practice.

Husserl argued that, for instance, geometry as a scientific practice had become divorced from the realities that had given rise to it. A square, as an abstract entity, is far removed from, say, a four-sided plot of land; and in glossing the distinction, science had lost sight of the nature of the connection between abstract and specific, the very connection that lent it validity. Squares, triangles, number and other mathematical abstractions have their origin in our experience of the world. Abstract categories are derived from concrete entities and experiential phenomena, not the other way around; and so, for Husserl, an exploration of the foundations of mathematics must begin with the study of experiential phenomena.

It is worth remembering the context in which Husserl's work was conducted. Husserl was a mathematician at a point where the very foundations of mathematics were in question. Events such as the advent of non-Euclidian geometries, or Godel's demonstration of the inherent incompleteness of formal systems of logic had assaulted the notion of mathematics as an objective formalisation of the world. Husserl sought, in effect, to remind science and mathematics of their fundamentally subjective nature, and indeed to reconstruct them through a thoroughgoing examination of the phenomena of human experience on which they were founded.

However, it was a student of Husserl's, Martin Heidegger, who would have the most profound influence in the development of phenomenological thought as we know it now, principally through his *Being and Time* (Heidegger, 1927). In fact, he would do it through a rejection of Husserl's basic assumptions. Like Husserl, he was engaged in the development of a philosophy of experience. However, Heidegger wanted to take Husserl's basic position further. Husserl had rejected the primacy of abstract, decontextualised entities of science and mathematics; but, Heidegger observed, in his reasoning, he had retained a mentalistic model that placed the focus of experience *in the head*. To Heidegger, this mentalistic perspective could not be sustained; it retained the very primacy of theory over practice that phenomenology rejected. For Heidegger, everyday experience happened not in the head, but out in the world.

Heidegger's "hermeneutic phenomenology" rejected the detached, mentalistic intentionality of Husserl's "transcendental" form. Where Husserl had conceived of a progression from perception to meaning to action, Heidegger stressed how we ordinarily act in a world that is already organised in terms of meaning and purpose. Heidegger took "shoot first, ask questions later" not as an imperative, but as a description of our mode of being.

Heidegger's phenomenology is not entirely new to HCI. It was one of the elements on which Winograd and Flores (1986) based their analysis of computational theories of cognition. In particular, they were concerned with Heidegger's distinction between "ready-to-hand" and "present-at-hand." Heidegger argued that the ontological structure of the world is not a given, but arises through interaction. As an example, consider the mouse connected to my computer. Much of the time, I act *through* the mouse; the mouse is an extension of my hand as I select objects, operate menus and so forth. The mouse is, in Heidegger's terms, *ready-to-hand*. Sometimes, however, for instance on those occasions when I reach the edge of the mousepad and cannot move the mouse further, my orientation towards the mouse changes; now, I become conscious of the mouse mediating my action, and the mouse becomes the object of my attention as I pick it up and move it back to the centre of the mouse-pad. When I act on the mouse in this way, being mindful of it *as* an object of my activity, the mouse is *present-at-hand*. Heidegger's concern with this distinction is not simply to observe that I have different ways of orienting towards objects; his observation is more radical. He argues that the mouse exists as a mouse only *because* of the way in which it can become present-at-hand. The origin of ontology, and the existence of entities, lies precisely in the way those moments make objects apparent. When an entity becomes present at hand, it is not simply that is *revealing itself*, or as if it was waiting all along to be discovered. Rather, it is through this moment of becoming present at hand that the object takes on an existence as an entity. The critical thing to observe here is that this can happen only through involved, embodied action. Winograd and Flores use this to illustrate that activity is constitutive of ontology, not independent of it.

Finally, here, the concept of "embodiment" features perhaps most strongly in the phenomenology of perception developed by Maurice Merleau-Ponty (1962). Merleau-Ponty saw perception as an active process, and one carried out by an embodied subject. The embodied nature of action (and actors) was central to Merleau-Ponty's philosophy. Dreyfus (1996) points out three different meanings of embodiment in Merleau-Ponty's work. The first is the physical embodiment of a human subject, with legs and arms, and of a certain size and shape; the second is the set of bodily skills and situational responses that we have developed; and the third is the cultural "skills," abilities and understandings that we responsively gain from the cultural world in which we are embedded. Each of these aspects, simultaneously, contributes to and conditions the actions of the individual, both in terms of how they understand their own embodiment (the "phenomenological body") and how it is understood by others (the "objective body"). Robertson (1997) has used Merleau-Ponty's work as the basis of a taxonomy of embodied actions for the analysis of group activity.

5.2 Other Approaches

Although I have associated the idea of embodiment with phenomenology, the same threads have run through other explorations of the foundations of interaction. I will consider two here, briefly, because of their influence on HCI.

The psychologist J.J. Gibson spent much of his career concerned with the problems of visual perception (Gibson, 1979). In the course of this work, he became disenchanted with the traditional psychological approaches to visual processing, because they separated perception from action, seeing from doing. For Gibson, visual perception could not be seen purely in terms of information processing, but had to be seen in the context of a creature acting in an environment. Gibson reframed the problems of perception and located them in the relationship between the creature and its environment. A central feature of his analysis was what he termed an “affordance.” Technically, an affordance is a property of the environment that affords action to appropriately-equipped individuals. Gibson used the perception of affordances as the basis of his ecological model of visual processing. Subsequently, others such as Norman (1988) and Gaver (1991; 1992) have found in ecological psychology, and particularly in the notion of affordance, a valuable tool for the analysis and design of interactive systems.

The relationship between meaning and action was also explored by Wittgenstein, whose later work was concerned with the philosophy of language and the nature of meaning. In *Philosophical Investigations* (Wittgenstein, 1958), he rejected the positivist view of a logic of meaning and truth that had characterised his earlier work. In its place, he developed a model of language not as an external expression of inner mental states, but as an *activity*; and it is language as action that gives it meaning. His famous dictum that “the meaning of a word is its use in the language” reflected an orientation towards an unbreakable link between language and practice. He coined the term “language-games”, “consisting of language and the actions into which it is woven”, to emphasise the way that it is only through featuring as a form of practical activity that language takes on meaning. Wittgenstein’s view of language as practice, and his critique of the notion of rule-following inherent in conventional approaches, feature strongly as aspects of Garfinkel’s ethnomethodological program.

My goal in presenting these various approaches here is not to suggest that they are all affiliated or even commensurable analysis of phenomena of interaction. Indeed, theoretical purists may bristle at the fact that the appear at all on the same pages. My goal at this point is simply to present an overview of the background. What we find is that it is perhaps not surprising that the design of interactive systems should increasingly reflect a concern with embodiment, since that concern has been one to which a wide variety of philosophical and theoretical approaches have attended throughout the twentieth century. This, in turn, provides us with hope that we can draw on these investigations in looking for a new foundation for the analysis and design of interactive systems.

6 FOUNDATIONS

The goal of the project outlined in this paper, then, is to uncover the foundations of an embodied approach to interaction. Although I have characterised both social and tangible computing in terms of embodiment, they have not typically been construed as elements of the same research programme. In addition, although many researchers working on social computing seek to take their orientation from foundational or theoretical approaches, work in tangible computing has, typically, been driven more by technological opportunities than by analytic understandings. One goal of this exploration is to redress the balance. On the basis, then, of themes drawn from the phenomenological backdrop presented earlier, what is presented in this section is an outline of a foundational model.[2]

The first question to ask, then, is what lessons should be drawn from the work presented earlier? What does phenomenology have to tell us about interaction? For the purposes at hand, I take three

2. This model is being developed in more detail elsewhere (Dourish, forthcoming).

main points from this work: that interaction is physically and socially embodied; that ontology arises out of activity; and that meaning subsists in embodied action.

The relationship between action and meaning is, in many ways, the crucial one here. Smith (1996) argues forcefully for an intentional view of computation, that is, one that is grounded in the meaning-bearing nature of computational representations. What I want to explore here, then, is how that is related to human action. From this perspective, the two pillars supporting a foundational model of interaction are *intentionality* and *coupling*.

Intentionality, loosely, is "about-ness." It describes a referential relationship between two entities. Words, images and ideas are intentional phenomena; they are *about* things, in a way in which rocks, carpets and trees are not. Intentionality is the essence of how entities bear meaning. Coupling refers to the degree of coordination of two elements, and to how that coordination is maintained.

As an example, let's turn back to the movement of the mouse that was discussed earlier in terms of Heidegger's notion of ready-to-hand. In normal use, the mouse moves directly with my hand, and the cursor on the screen moves directly with the mouse, so that there is an effective coupling of hand, mouse and cursor. The effect of this coupling is to render the entire system (hand, mouse, cursor) ready-to-hand so that my activities are organised in terms of higher-level actions such as selection and pointing, or even at a higher level, in terms of compiling code and saving files. When everything is working well, I can deal with the objects of the user interface in terms of similarly high-level meaning; I "register" the interface in these terms (Smith, 1996).

This is achieved through multiple levels of coupling. They can break down in different ways. The edge of the mousepad, as described above, poses problems for the coupling between hand movement and mouse movement; a broken mouse might introduce troubles for the coupling between mouse movement and cursor movement; and if my computer is so busy that it is not responding to user interface events, then the coupling between user interface action (pressing buttons or selecting menu items) and the application activity (such as compiling my program) might be interrupted.

The point to recognise here is not simply that embodied action operates on multiple levels. What is important is that, at the different levels and with different degrees of coupling, the entities with which the user interacts are also different. I register a set of pixels as a display artifact, as a button, or as the print function; the meanings assigned to the objects in the interface depend on the coupling of actions. Coupling and intentionality are directly related.

By implication, then, in order to manage meaning, we must be able to manage coupling. In order to talk about an object, we have to be able to stand back from it far enough to see it; we need to be able to control how we engage and disengage from it.

Coupling, then, is at the heart of our ability to work with artifacts and control them. Intentionality is an everyday phenomenon; arguably, it is *the* phenomenon of human experience, which works its way out in the interactions in which we engage with the world and with each other. It is rooted in our socialisation and our lives as social animals in a web of social and cultural relations which give meaning to everyday action. Fluid coupling provides us with the means to negotiate this web. Embodiment lies in the relationship between the two.

How should we understand tangible and social computing in these terms? Interestingly, it seems as though the essence of tangible computing is to eliminate coupling by emphasising directness. No more pushing a mouse around to manipulate virtual objects; let's move the real objects instead! However, if we see coupling as intrinsically tied to intentionality, then our perspective changes. What is important in computation is the meaning and referents of representations. What tangible computing does, by moving computation out into the world, is to open up new ways for us to be coupled to the intentional phenomena of computation. In particular, it provides new ways for us to explore them. What turns out to be important about tangible computing, then, is not the physical nature of the objects through which we interact, but with what they represent and how we use them. At the same time, social computing emphasises how context lends meaning, and places a primary emphasis on action rather than abstract representation. Embodied interaction provides us with a perspective on computational representation that takes action as a primary constituent.

The focus of the work presented here is interaction. Others have taken a similar perspective on other topics in computer science. Agre (1997) takes an embodied, interactional approach to the problems of artificial intelligence, discussing the problems of decontextualised abstraction and the mentalist perspective on representation and meaning. Smith (1996) presents the ontological foundations of an investigation of the very basis of computational altogether; again, participation is the basis from which ontology and meaning flow. The issue of how, in details, an embodied approach to interaction might relate to Agre's "deitic representations" or Smith's "registration" is a matter for further work.

7 CONCLUSIONS

What has been presented here is the outline of an embodied approach to HCI. This approach weaves together recent threads in research into interactive systems, and in particular concerns with social and tangible computing. The goal of the project reported here is to place recent developments on a stronger foundation, and to foster a recognition of their common orientation towards a set of shared concerns. However, on the occasion of this issue, it seems appropriate in addition to consider what implications this approach holds for the future of interactive system development.

For instance, consider the advent of the "invisible computer." Norman (1998) has proclaimed the invisible computer to be the natural goal of PC development, while Fishkin et al. (1998) give "invisible user interfaces" as the goal of their work. The framework presented here questions that idea. It is hard to be actively engaged with something that isn't there. When UI critics observe, "I don't want to use a word processor; I just want to *write*", and cite the ease of use of pen and paper as an example, they presumably forget the years they spent learning to use pen and paper effectively. When I write with a pen, I become coupled with it in such a way that my actions can be carried out at the level of words and sentences, not marks on paper. The pen is still critically present, though. An invisible pen would be a hard thing to use. The notion of the invisible interface confuses coupling with visibility.

An interesting perspective on the notion of invisible user interfaces, or other interfaces that recede into the background, is raised by recent work that uses the computer interface as a site for creative design. For instance, the "intimate interfaces" presented by Strong and Gaver (1996) are anything but invisible. They are explicitly meant to be engaging. Dunne and Gaver (1997) discuss the role of "artists-designers", and point out that, while the role of the designer in HCI might often be thought of as being to beatify, they see the role of the artist-designer as being to engage and to question. What is notable about their designs is their physicality; their embodiment serves not to render them invisible, but rather to encourage a deeper engagement.

Embodied interaction, then, suggests that the future of interaction lies not in the interface "disappearing", but rather in the interface becoming even more visible, or rather, available for a wider range of engagements and interactions. The question is, what form will that heightened visibility take? Recently, a new thread of interaction research has arisen around "cooperative buildings", based on the integration of information technologies and architecture (Streitz et al., 1998). Here, the tables are turned; the interaction is not only situated, but we are situated in it.

A range of open questions remain. The framework itself is still in development, and only an outline has been sketched here. In addition, what has been presented here is largely analytic, rather than design-oriented. However, it has proven to be a powerful lens through which to study current phenomena of interaction; and it may similarly be useful for looking into the future.

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