

An Embodied Approach for Engaged Interaction in Ubiquitous Computing

Mark O. Millard¹ and Firat Soylu²

¹ School of Library & Information Science, Indiana University

² Department of Cognitive Science, Indiana University

220 North Rose Bloomington, IN

{mmillard, fsoylu}@indiana.edu

Abstract. A particular vision of ubiquitous computing is offered to contribute to the burgeoning, dominant interaction paradigm in human-computer interaction (HCI). An engaged vision of ubiquitous computing (UbiComp) can take advantage of natural human abilities and tendencies for interaction. The HCI literature is reviewed to provide a brief overview of promising interaction styles and paradigms in order to situate them within ubiquitous computing. Embodied interaction is introduced as a key theoretical framework for moving UbiComp forward as an engaged interaction paradigm.

Keywords: ubiquitous computing, HCI, embodied interaction, tangible interaction.

1 Introduction

Human-computer interaction (HCI) is a diverse, multidisciplinary research and practice domain. The multidisciplinary history of HCI is, in part, demonstrated by the various monikers (e.g., human factors, ergonomics) it has shared throughout its short history and also by the sheer number of academic disciplines that contribute and concern themselves with HCI problems. Preece et al. [1] note the multidisciplinary nature of HCI in a diagram that represents over 20 different components including academic disciplines, other interdisciplinary fields, and design practices that have a significant relationship with the HCI domain. This group of disciplinary contributors continues to grow as the issues of UbiComp continue to be uncovered [2]. discusses the “three faces of HCI” acknowledging several broad fields of historical influence, from industrial engineering to cognitive psychology. The extensive multidisciplinary nature of HCI highlights its historical character and resiliency, but also the paradigm challenges it faces. An analysis of the literature indicates that HCI is in the midst of a significant paradigm shift that is causing a fundamental shift in the problems, theories, methods and models needed within HCI; which leads us to the goal of this paper. This paper is not intended to propose a solution to any single problem, but rather is intended to illustrate a particular view of interaction within ubiquitous computing in order to raise questions that clarify Weiser’s [3] vision of calm computing.

In order to understand the potential trajectory of HCI, this paper intends to clarify the scholarly discourse within HCI by providing an analysis and review of the literature

surrounding direct manipulation, multi-touch interaction (MTI), tangible user interfaces (TUI), and ubiquitous computing (UbiComp). In addition, the paper will attempt to situate these HCI concepts within the theoretical framework of embodiment / embodied interaction. Embodied interaction is the theoretical foundation that connects each of these seemingly disparate HCI concepts and provides a foundation for an 'engaged' vision of UbiComp.

2 Theoretical Foundations: Embodied Interaction

For most of HCI's history it has been approached theoretically from a cognitivist / information-processing perspective. Practically this illustrates a disconnected approach as the "human using an application or tool, or as a communicative process between human and machine" [4]. The Cognitivist perspective overlooks, as Heidegger posits, the sense of 'being', and the ways that we encounter the world and act through it to define meaning and action; a distinction further made with ready-to-hand and present-at-hand [5]. These are necessary theoretical elements that facilitate a more complete understanding of human interaction in the world. This paper argues that this perspective is necessary when conceptualizing interaction in ubiquitous computing. The notion of embodiment is not a new one, but has been a common theme throughout philosophy and cognitive science and is at the center of a branch of philosophy called phenomenology which is principally concerned with the elements of the human experience, including questions of ontology and epistemology [5]. From this perspective, humans are seen as embodied beings with sensory, perceptual, and cognitive abilities that are "inextricably tied to our physical being, and the need for that being to function as it is situated in a dynamic, time-pressured world" [4]. Dourish [5] explicitly extends embodiment to HCI through his concept of 'embodied interaction' noting "we encounter, interpret, and sustain meaning through our embodied interactions with the world and with each other." He continues by explicitly linking tangible computing and social computing with embodied interaction by highlighting that tangible computing allows us to create and communicate our meaning and actions and encourages users to "explore, adopt, adapt and incorporate interactive technology" into our everyday worlds [5]. But why choose embodiment as a key theoretical foundation for conceptualizing UbiComp interaction? One particularly good reason is the existence of research from other disciplines that support the underlying principles of embodiment for communicating, learning, and socializing. For HCI it makes sense to design technologies, interfaces, and interaction that mimic that which humans are already naturally good at doing, and the ways that they naturally interact. For example, research in educational psychology supports the idea of embodiment as a foundation for natural and effective human interaction, learning, and development. Klemmer et al. [6] provide analysis of educational theorists such as Piaget, Montessori, and others who discuss the importance of thinking by doing, and learning by doing, as well as the role of gesture in communication. Much of this research highlights the importance that ones "direct physical interaction with the world is a key constituting factor of cognitive development during childhood" [6]. In relation to the current dominant GUI paradigm, Klemmer et al. [6] even go so far as to state that primarily interacting through a keyboard and mouse can have a potentially hindering effect on a user's ability to think, to be creative, and to communicate, because the use of bodily

movement and gesture is so important in these processes. This signals a potential strength of embodied interaction, and its recognition that space is not simply a “container for our actions”, but is a “setting within which we act” [12], and it signifies how we encounter the world and act through it to define meaning and action.

Another unique aspect of embodiment is that it tightly links the physical and social worlds in which we act. In fact, Dourish [5] contends “embodiment is the common way in which we encounter physical and social reality in the every day world” by noting that humans are “enmeshed in a world of physical facts” and that our daily experiences are also extensively social as “we interact daily with other people and we live in a world that is socially constructed” [5]. Although extremely important a detailed discussion of the social aspects of UbiComp are beyond the scope of this paper. However, there has been a significant amount of research and discussion regarding the importance of social aspects of computing and interaction within UbiComp [3, 5, 7, 8, 9, 11], and others have studied the importance of gesture in social and communicative processes [6, 12].

This section has discussed the theoretical foundation from which ubiquitous computing should move forward. Although the application of embodiment and embodied interaction is quite new, it holds great promise for HCI as it shifts toward ubiquitous computing and begins to reconceptualize interaction. The paper will now focus discussion on ubiquitous computing and the developing HCI interaction styles and techniques that will most effectively align with UbiComp and the theory of embodied interaction.

3 Ubiquitous Computing: Envisioning the Next Paradigm

Ubiquitous computing (UbiComp) is a fundamental shift in interaction and computing. Although this nascent term is sometimes used in too broad of context, much of the early work on UbiComp assumes Weiser’s vision, which conceives “a new way of thinking about computers, one that takes into account the human world and allows the computers themselves to vanish into the background” [13]. Recently, there has been a growing debate about the direction in which to proceed with Weiser’s vision of ‘calm computing’. In response, this paper will proceed with a view based on Rogers [10] conceptualization that engages users. Rogers proposes an alternative agenda “which focuses on designing UbiComp technologies for engaging user experiences. It argues for a significant shift from proactive computing to proactive people; where UbiComp technologies are designed not to do things for people but to engage them more actively in what they currently do. Rather than calm living it promotes engaged living... Furthermore, it argues that people rather than computers should take the initiative to be constructive, creative and, ultimately, in control of their interactions with the world – in novel and extensive ways” [9].

Since UbiComp is still a developing paradigm, it is referred to in the literature in different ways (e.g., pervasive computing, context-aware, wearable computing, calm computing, third wave, post-WIMP, post-cognitivist) and the categorization of the various UbiComp models, theories and interaction styles is still being debated within HCI. Nevertheless, HCI researchers are beginning to understand the shift in interaction, from a dominant cognitive/information-processing view to a more embodied and social-oriented view [5, 8, 9, 12]. This paradigm shift demonstrates a fundamental

conceptual change for the role of interaction in HCI. This paradigm shift is well supported in the literature, yet there is extensive scholarly discourse about what form this new wave of interaction should take. Since the debates are still in progress, it is difficult to predict exactly where the debate will lead UbiComp, but this paper claims that embodied interaction has the ability to situate many of the most promising UbiComp interaction styles and techniques such as: tangible interaction, multi-touch interaction, among others. There are so many potentially interesting new interaction and interfaces styles, methods and techniques currently being researched including: haptics, ambient sound, natural-language, gesture-based, multi-touch, and tangible interaction that it is difficult to limit our discussion. However, we have focused our discussion on three particularly interesting interaction styles that naturally make use of the principles of embodied interaction and can drive the quality of UbiComp interaction: direct manipulation, tangible user interfaces (TUI), and multi-touch interaction. It is important to remember our discussion, thus far, regarding UbiComp and the theoretical framework of embodied interaction, as these are the important foundations from which interaction will be understood.

3.1 Direct Manipulation

The direct manipulation interaction style began in the late-1960s and 1970s in research labs at Stanford, MIT, Maryland and Xerox PARC [16]. It was the pairing of the mouse, graphical user interface (GUI), software, multiple tiled windows, and eventually hypertext that have contributed to and sustained the dominance of the direct manipulation interaction style for nearly three decades [15, 16]. Ben Shneiderman brought organization to the concept by describing direct manipulation interfaces as having the following underlying characteristics: 1) Continuous representation/visibility of the objects and actions of interest, 2) Physical actions or presses of labeled buttons instead of complex syntax, 3) Rapid incremental reversible operations whose effect on the object of interest is immediately visible [18]. The popularity and success of this interaction style is attributed to its “learnability”, ease of use, and the availability of immediate feedback [1, 18]. Direct manipulation systems also “tend to have a similar look and feel, and empower users’ sense of control in executing and evaluating tasks” [1].

Regardless of the strengths and popularity of direct manipulation, the models, metaphors and interfaces associated with this style do have drawbacks. For example, as direct manipulation interfaces become more complex the metaphors can begin to confuse the user [1]. Other HCI researchers also echo the complexity issues by suggesting that increasing complexity of individual direct manipulation interfaces aggregate to create more complexity for the user [15]. The complexity issue appears to be a key shortcoming in the literature for direct manipulation. This is where new interaction styles such as tangible interaction, and multi-touch interaction may be able to alleviate the “complexity problems”, by releasing users from the confines of their desktop computer, mouse and keyboard, and “coupling digital information to everyday physical objects and environments” [36]. This paper argues that we should not immediately abandon direct manipulation. Perhaps these “complexity problems” are the fault of the GUI and WIMP interaction styles and the limited desktop computing metaphors that are based in the cognitive/information-processing perspective. Nearly twenty-five years ago Shneiderman [18] notes that direct manipulation systems “offer

the satisfying experience of operation on visible objects. The computer becomes transparent, and users can concentrate on their task". This helps to illustrate that the GUI and WIMP interaction style may be the limiting factor, not the underlying characteristics of direct manipulation. It's possible that we may look to direct manipulation to provide an already proven foundation for new interaction styles in ubiquitous computing. As we will see in the next section, although not explicit, Tangible interaction holds many similarities by coupling physical objects with digital artifacts for directly acting (i.e., manipulating) in the world—this is direct manipulation in its purest form.

It is apparent that the current dominant interaction style (i.e., direct manipulation) faces many problems as we move into the complexity of third wave computing, yet its strengths, familiarity, and popularity provide it an opportunity to be re-examined before being cast aside. This paper argues that the foundational characteristics of direct manipulation can provide a basis for new interaction styles such as tangible interaction and multi-touch interaction. In this case we look to Weiser himself for justification of the re-examination of direct manipulation in discussing older technologies he notes that each are "bountiful sources of innovation, and have required reopening old assumptions, and re-appropriating old technology into new contexts" [3].

3.2 Tangible Interaction

There has been a significant amount of research linking tangible interaction with both UbiComp and embodied interaction [5, 12, 32]. In fact, Tangible User Interface (TUI) is seen as a different approach to Mark Weiser's vision of ubiquitous computing, rather than make pixels melt into an interface, TUIs use physical forms that fit seamlessly into a user's physical environment" [14]. This establishes the impetus for moving forward with an exploration of tangible interaction within ubiquitous computing. The notion of TUI involves: interactive surfaces, coupling of physical objects and digital bits, and ambient media for increase feedback and background awareness [36]. To make this connection more explicit a discussion of TUI incorporates these elements noting, "TUI also utilizes malleable representations, such as video projections and sounds, to accompany the tangible representations in the same space to give dynamic expression of the underlying digital information and computation" [14]. Hornecker & Buur [20] have recently reconceptualized TUI as 'tangible interaction' in order to broaden Ishii & Ullmer's earlier conception, which focused mostly on the interface aspect of TUI which resulted in a data-centered view of tangible interaction and does not encompass other complementary views that have been explored (i.e., expressive-movement-centered, and space-centered). This broadening helps to situate tangible interaction squarely within the realm of embodied interaction and contributes to its larger research agenda by incorporating space and movement.

Advantages of tangible interaction include: it encourages interaction with, and through the world; encourages two-handed interaction; allows for more parallel input by the users; leverages the natural human abilities for physical object manipulation; takes advantage of our developed spatial reasoning; provides for more direct and manipulable interface elements; and affords for multi-modal and collaborative use [21]. Tangible interaction is "not about making 'computers' ubiquitous per se, but rather about awakening richly-afforded physical objects, instruments, surfaces, and

spaces to computational mediation, borrowing perhaps more from physical forms of the pre-computer age than the present” [36]. An interesting example of tangible interaction is seen through a TUI prototype telephone answer machine. The Marble Answering Machine design utilized tangible and visible marbles (i.e., the physical ‘atoms’) to display and interact with the answering machine (i.e., the digital ‘bits’). “This physical embodiment of incoming phone messages as marbles demonstrated the great potential of making digital information graspable by coupling bits and atoms” [36]. This is just one interesting example in which tangible interaction capitalizes upon our familiarity with physical interactions in the everyday world [5]. It is clear from these advantages and examples that tangible interaction aligns well with each of earlier concepts, as well as multi-touch interaction, and provides a much richer set of options for UbiComp interaction.

3.3 Multi-touch Interaction

Multi-touch interaction has recently excited many consumers and the popular press. With the recent commercial releases of the Apple iPhone, and Microsoft’s Surface Computing initiative, one can begin to quickly realize the power of this form of interaction. Although some analysts argue over the impact and success of the multi-touch interface [24], if we situate multi-touch within a UbiComp perspective and combine it with TUI, and utilize an embodied interaction perspective, we begin to see great possibilities and connections that were not visible before.

There are distinct advantages of multi-touch interaction that have not yet been clearly articulated in the UbiComp literature. Advantages include: the ability to provide an extra layer of interaction within TUI, such as touchable surfaces on real-physical objects; multi-touch can extend the benefits of soft machines and malleable (softwired) interfaces to provide improved interaction, and increased flexibility and configurability [22, 23]; provide direct physical interaction through multi-touch surfaces, and with the addition of haptic technology, can provide “tactile sensations and controls to interactions” [24]; provide for two-handed direct interaction; support gesture based interaction; can support multi-user collaborative environments for better collaboration, coordination and parallel problem solving [25]; and assist TUI in linking physical tangible objects with digital realm.

This list of advantages is by no means comprehensive, but begins a conversation regarding the interaction advantages of multi-touch interaction within an embodied framework. Although there has been a considerable amount of research conducted on multi-touch over the past twenty years, much of the research literature has focused on the technological aspects of getting these systems to work [26, 27, 28]. There is also a valuable body of literature pertaining to general input studies, and specific interaction methods and techniques with prototypes [25, 29, 30 31]. However, now that numerous commercial versions of multi-touch systems are being realized, there is great opportunity for studying not only the properties and issues involved in multi-touch interaction, but for also the issues of interaction with UbiComp, tangible interaction, and other multimodalities.

What is important to recognize in regard to interaction within UbiComp environments, is the usefulness of combining interaction styles for multi-modal interaction [4, 5, 12, 33]. This includes interaction modalities such as: multi-touch interaction, haptics, ambient sound, tangible user interfaces, natural language, among others. The

embodied view of interaction focuses on humans in the world, and thus can prescribe a broader view of interaction that is more analogous to the ways we naturally interact in the world [32]. By employing the embodied interaction perspective, many of these new combined forms of interaction can flourish in UbiComp environments bringing us ever closer to the realization of true forms of interaction.

4 Conclusion

Although this paper has focused on embodied interaction as the primary theoretical framework for incorporating the many complex components of UbiComp, it is important to note that there are other perspectives that must be addressed in cooperation such as new theories and approaches that consider the real-life practices of people situated in social and cultural contexts including: activity theory, distributed cognition, ethnomethodology, external cognition, and situated action [8, 9, 34, 35, 36]. Although it has not been explicitly discussed in this paper, one particularly important goal for the HCI UbiComp community is to gain an understanding of the social issues that are embedded within HCI (i.e., aspects of anxiety, control, privacy, trust, and collaboration). These important questions were raised even as Weiser first conceptualized the idea of UbiComp. He contemplated “If computers are everywhere they better stay out of the way, and that means designing them so that the people being shared by the computers remain serene and in control.” [3]. This notion of embedding computers in the environment underscores the importance of considering the social and cultural aspects of UbiComp. Unfortunately, “thinking and talking about computerization as the development of socio-technical configurations, rather than as simply installing and using a new technology, is not commonplace” [37].

The underlying importance of these social issues helped guide the deliberate selection of interaction styles and theories for this paper, which involves leveraging an ‘engaged’ multi-modal approach to interaction, and is explicitly aligned with Rogers [10] “engaged” vision of UbiComp. The vision of Rogers, Dourish, and others is more in sync with the ways that humans naturally interact in the world. Humans are more satisfied, and learn more about the world, and themselves, when they are engaged in it, not when things are being done on their behalf. The claim within is that an engaged approach to UbiComp utilizing an embodied perspective can help researchers and practitioners think through the social aspects since “embodiment is a unifying principle for tangible and social computing” [5]. Having an understanding that the physical and social are inextricably intertwined affords a holistic perspective that we did not have with Cartesian dualism / cognitivist perspective, and is a perspective that HCI will certainly need as it moves forward.

References

1. Preece, J., Rogers, Y., Sharp, H.: *Interaction Design*. Wiley, Chichester (2002)
2. Grudin, J.: Is HCI homeless? In search of inter-disciplinary status. *Interactions* 13(1), 54–59 (2006)
3. Weiser, M., Brown, J.S.: *The coming age of calm technology* (1996), <http://www.ubiq.com/hypertext/weiser/acmfuture2endnote.htm> (retrieved 09/15/2007)

4. Quek, F.: Embodiment and multimodality. In: *Proceedings of ICMI 2006 International Conference on Multimodal Interfaces*, pp. 388–390. ACM Press, New York (2006)
5. Dourish, P.: *Where the Action Is*. MIT Press, Cambridge (2001)
6. Klemmer, S.R., Hartmann, B.: How bodies matter: Five themes for interaction design. In: *Proceedings of Design of Interactive Systems*, vol. 74, pp. 140–149 (2006)
7. Abowd, G., Mynatt, E., Rodden, T.: The human experience of ubiquitous computing. *Pervasive Computing* 1(1), 48–57 (2002)
8. Kaptelinin, V., Nardi, B., Bødker, S., Carroll, J., Hollan, J., Hutchins, E., Winograd, T.: Post-cognitivist hci: second-wave theories. In: *Proceedings of CHI 2003 Extended Abstracts on Human factors in Computing Systems*, pp. 692–693. ACM Press, New York (2003)
9. Rogers, Y.: New theoretical approaches for human-computer interaction. *Annual Review of Information Science and Technology* 38, 87–143 (2004)
10. Rogers, Y.: Moving on from Weiser's vision of calm computing: Engaging UbiComp experiences. In: Dourish, P., Friday, A. (eds.) *UbiComp 2006*. LNCS, vol. 4206, pp. 404–421. Springer, Heidelberg (2006)
11. Vogiazou, Y., Reid, J., Raijmakers, B., Eisenstadt, M.: A research process for designing ubiquitous social experiences. In: *Proceedings of NordiCHI 2006 the 4th Nordic Conference on Human-computer Interaction*, pp. 86–95. ACM Press, New York (2006)
12. Williams, A., Kabisch, E., Dourish, P.: From interaction to participation: Configuring space through embodied interaction. In: Beigl, M., Intille, S.S., Rekimoto, J., Tokuda, H. (eds.) *UbiComp 2005*. LNCS, vol. 3660, pp. 287–304. Springer, Heidelberg (2005)
13. Weiser, M.: *The Computer for the 21st Century*. Scientific American (1991)
14. Ishii, H.: Tangible User Interfaces. In: Sears, A., Jacko, J. (eds.) *The Human-Computer Interaction Handbook: Fundamentals, Evolving Technologies and Emerging Applications*, pp. 469–487. Lawrence Earlbaum Associates, New York (2008)
15. van Dam, A.: Post-WIMP user interfaces. *Communications of the ACM* 40(2), 63–67 (1997)
16. Myers, B.A.: A brief history of human computer interaction technology. *ACM Interactions* 5(2), 44–54 (1998)
17. Shneiderman, B.: Direct Manipulation: A Step Beyond Programming Languages. *Computer* 16(8), 57–69 (1983)
18. Hornecker, E., Buur, J.: Getting a grip on tangible interaction: a framework on physical space and social interaction. In: *CHI 2006: Proceedings of the SIGCHI conference on Human Factors in computing systems*, pp. 437–446. ACM Press, New York (2006)
19. Fitzmaurice, G.W., Ishii, H., Buxton, W.A.S.: Bricks: laying the foundations for graspable user interfaces. In: *CHI 1995: Proceedings of the SIGCHI conference on Human factors in computing systems*, pp. 442–449. ACM Press, New York (1995)
20. Nakatani, L.H., Rohrlach, J.A.: Soft machines: A philosophy of user-computer interface design. In: *Proceedings of CHI 1983 SIGCHI conference on Human Factors in Computing Systems*, pp. 19–23. ACM Press, Boston (1983)
21. Villar, N., Gellersen, H.: A malleable control structure for softwired user interfaces. In: *Proceedings of the 1st international conference on Tangible and embedded interaction*, pp. 49–56. ACM Press, Baton Rouge (2007)
22. Nichols, S.: New interfaces at the touch of a fingertip. *Computer* 40(8), 12–15 (2007)
23. Shen, C., Ryall, K., Forlines, C., Esenther, A., Everitt, K., Hancock, M., Morris, M.R., Vernier, F., Wigdor, D., Wu, M.: Interfaces, Interaction Techniques and User Experience on Direct-Touch Horizontal Surfaces. *IEEE Computer Graphics and Applications*, 36–46 (September/October 2006)

24. Han, J.Y.: Low-cost multi-touch sensing through frustrated total internal reflection. In: UIST 2005 Proceedings of the 18th annual ACM symposium on User interface software and technology, pp. 115–118. ACM Press, New York (2005)
25. Matsushita, N., Rekimoto, J.: HoloWall: designing a finger, hand, body, and object sensitive wall. In: Proceedings of the 10th annual ACM symposium on User interface software and technology, pp. 209–210. ACM Press, Banff (1997)
26. Wilson, A.: TouchLight: An Imaging Touch Screen and Display for Gesture-Based Interaction. In: Proceedings of ICMI 2004 International Conference on Multimodal Interfaces, pp. 69–76. ACM Press, New York (2004)
27. Buxton, W., Hill, R., Rowley, P.: Issues and techniques in touch-sensitive tablet input, Computer Graphics. In: Proceedings of SIGGRAPH 1985, pp. 215–223. ACM Press, New York (1985)
28. Forlines, C., Wigdor, D., Shen, C., Balakrishnan, R.: Direct-touch vs. mouse input for tabletop displays. In: CHI 2007: Proceedings of the SIGCHI conference on Human factors in computing systems, pp. 647–656. ACM Press, New York (2007)
29. Geibler, J.: Shuffle, throw or take it! Working efficiently with an interactive wall. In: CHI 1998: Proceedings of the SIGCHI conference on Human factors in computing systems, pp. 265–266. ACM Press, New York (1998)
30. Dourish, P.: Seeking a Foundation for Context-Aware Computing. *Human-Computer Interaction* 16(2), 229–241 (2001)
31. Tripathi, A.K.: Computers and the embodied nature of communication: Merleau-Ponty's new ontology of embodiment. *Ubiquity* 6(44), 1–9 (2005)
32. Bodker, S.: When second wave HCI meets third wave challenges. In: Proceedings of NordiCHI 2006, the 4th Nordic Conference on Human-computer Interaction, pp. 1–8. ACM Press, New York (2006)
33. Nardi, B.: *Context and Consciousness: Activity Theory and Human-Computer Interaction*. MIT Press, Cambridge (1995)
34. Suchman, L.: *Human-Machine Reconfigurations: Plans and Situated Actions*. Cambridge University Press, Cambridge (2006)
35. Kling, R.: What is social informatics? *The Information Society* 23(4), 205–220 (1999)
36. Ishii, H., Ullmer, B.: Tangible bits: Towards seamless interfaces between people, bits and atoms. In: Proceedings of CHI 1997, pp. 234–241. ACM Press, New York (1997)