Personal Statement

Anind K. Dey
Senior Researcher, Intel Research Berkeley
&
Adjunct Assistant Professor, EECS Department, UC Berkeley

Research:

End-user control in interactive systems is key to an effective user experience. Control in ubiquitous computing systems is especially important as much of what occurs in these systems is based off of implicit user input and is, therefore, invisible to the user. My research focuses on sensing-based interaction, the use of sensing systems to improve the human-computer experience, by putting end users in control of the systems they use. In particular, my research involves building applications, middleware and tools that programmers, designers and end users can use to build applications in the cross-section of human-computer interaction and ubiquitous computing.

My thesis research concentrated on architectural support for building *context-aware* applications, applications that enable users to interact implicitly with their ubiquitous computing environments. *Context-aware computing* involves collecting implicit information (or *context*) from the environment to more appropriately target application services for supporting dynamic user needs. The instantiation of my investigations into this area is the Context Toolkit, a software toolkit that simplifies the design and building of context-aware applications [5]. The Context Toolkit has made it easier to reproduce existing applications. More importantly, however, the toolkit has made it easier to build more complex applications that use a wider variety of context in a number of different ways to support users [5]. In addition, the toolkit has enabled me to investigate other issues that have not been appropriately addressed in context-aware computing: maintaining users' control over the information collected about them (*i.e.* privacy) [3,9]; dealing with ambiguous or conflicting context [6]; providing users with the ability to control how applications should adapt to their context (*i.e.* end-user programming) [15]; and, designing and evaluating infrastructure software with a user-centered perspective [8]. My research on the Context Toolkit and the general area of context-awareness has been published widely, in a number of journals and conferences, including the anchor article in a special issue of the HCI Journal on context-awareness [5].

Over the past two years, as a researcher at Intel and an Adjunct Professor at UC Berkeley, I have concentrated on a related vein of research, supporting end-users' control in sensor-rich, ubicomp environments. Because so much of the interaction that occurs in ubicomp environments is implicit and dynamic, it is essential to put users in control. The implicit nature of ubicomp interaction creates situations where users may not understand why their ubicomp environment is behaving in a particular way. The dynamic nature of these environments means that there is greater potential for an application designed by a programmer to become outdated, as users, their tasks and their environments change. We can empower users in ubicomp environments, by giving them feedback to support understanding and control to support action. This will allow users to have less frustrating and more meaningful, useful and engaging interactions with each other and their ubicomp environments. There are three main issues I and my students have been working on to put users in control: Supporting end-user management of privacy in a world of ubiquitous sensing; using peripheral displays of information to avoid information overload in a ubiquitous information environment; and, end-user programming of ubicomp environments.

End-User Management of Privacy in Ubiquitous Computing Environments

In a ubicomp environment, it is expected that there will be a tremendous amount of information that will be sensed. One of the criticisms of ubiquitous computing is that it will enable constant invasions of privacy, by allowing people and institutions to constantly monitor the activities of others. We have been investigating user interaction techniques for controlling the flow of sensing information without overwhelming the user with mediating constant requests for their personal information [9]. After interviewing and surveying a number of users to determine what factors play a role in managing one's privacy [10], we designed and implemented a privacy management system for ubicomp. Our approach is to allow the user to pre-

configure the desired flow of information, at specified levels of precision, to different users in different situations. When a request arrives for a user's current or past information, the user is not required to be notified or handle the request. To make this pre-configuration tractable, we minimize the effort required for it by asking the user to provide a minimal amount of information for each configuration. In addition to this work, we have tried to understand why existing systems for maintaining privacy on the Web and in ubicomp (at least, our current form of ubicomp) have failed. We have analyzed our own system along with a large number of other privacy-affecting systems to understand what pitfalls designers of such systems may fall into [11]. We have also performed user studies to try and understand how much control and loss of privacy users have when using context-aware services [2,3]. Our goal is to understand what are the social and technical issues involved in supporting privacy in ubicomp environments and to provide guidelines for designing privacy-supporting applications.

Peripheral Displays of Information

In today's information age, users are already being overloaded with information. Information comes in the form of email (and spam), voicemail, cell phone calls, instant messengers, pages, web pages, video and print media. In a ubicomp environment, where far more information will be generated and shared, users will have to contend with far greater demands for their attention. To combat this, we are investigating the use of peripheral displays of information, displays that present information to users without overloading their main perceptual channels. If a user is using a computer, rather than present them with information on their computer screen and distract them from their current task, information can either be presented in their visual periphery or using another perceptual channel that is not being overloaded (*e.g.* tactile or sound). In particular, we have been investigating techniques and tools for building effective peripheral displays and building displays for supporting particular applications. We have built an initial toolkit, the Peripheral Display Toolkit, that eases the building of peripheral displays [13]. We have also built displays to support knowledge of Berkeley residents about the health of the Berkeley community [1] and displays that support users in being aware of remote family members. In addition, we have been examining how to modify techniques for evaluating peripheral displays. Most evaluation techniques focus on efficiency and task-based activities that do not apply to peripheral displays. Our work has focused on examining existing traditional techniques for evaluation and modifying them to be appropriate for peripheral displays [12]. Our goal is to help define metrics for evaluating displays and techniques for evaluation, in order to improve the effectiveness of peripheral displays.

End-User Programming of Ubiquitous Computing Environments

With my work on the Context Toolkit, it is easier for programmers to build context-aware applications. However, in ubicomp environments, it is not the programmer who will know what response to sensed information and activities is most appropriate. Instead, it is the people who occupy those environments that will have the best knowledge about how their physical and computational environments should respond to their activities. Most of these people are not able to program, in the traditional sense. We are performing research on a variety of interaction techniques to support end-users in building sensor-rich applications without writing a single line of code. Some of the techniques include a visual programming environment where users configure the responses an environment should have to their actions [15], a tangible programming environment where users also write context-based rules with physical objects [4], and programming-by-demonstration, where the user physically acts out how the environment should respond and the environment learns from these demonstrations [7]. We are also working on expanding the Context Toolkit to support designers that use tools like Macromedia Flash, as opposed to programmers writing source code, in building context-aware applications and monitoring and control interfaces for them [14]. The goal of this work is to expand the group of people that can build compelling ubiquitous computing applications, to support more lightweight prototyping of ubiquitous computing applications and to enable a more widespread use of ubiquitous computing applications.

Funding:

My funding for these projects has come from two medium-sized NSF ITR grants (Co-PI on one, Senior Personnel on the other) and from my employer, Intel. The first NSF grant is centered on the area of context-aware computing and the second focuses on providing information technology to developing communities.

Teaching and Supervision:

As an Adjunct Professor, I teach one class a year at UC Berkeley. In my first year, I co-taught a graduate class on tangible computing, with a professor from Mechanical Engineering and a professor from Art Practice. The goal of this class was to merge the disciplines of computer science, mechanical and electrical engineering and art to achieve a well-rounded understanding of the experience and interaction of active tangible artifacts. I am currently teaching a graduate class on ubiquitous computing. While the class has a decidedly human-computer interaction focus, it attempts to provide a comprehensive view of the issues involved in designing, prototyping and evaluating ubiquitous computing systems. It draws from the areas of HCI, machine learning, distributed systems and software engineering. In my classes, I have accepted a small number of exceptional undergraduates and have had a mix of students from the School of Information Management and Systems, Electrical Engineering and Computer Science, Mechanical Engineering, and Art Practice.

I can teach undergraduate and graduate courses in HCI, including introductory classes, and classes that focus on evaluation, toolkits, and user interface design. As well, I can teach introductory courses in software engineering, distributed computing and computer graphics. I would like to develop a series of courses on the topic of mobile and ubiquitous computing, focusing on user-interaction paradigms, context-awareness and distributed systems.

One of the most rewarding aspects of my academic career has been the opportunity to teach, to interact with and to supervise students. As an undergraduate student, I tutored other students in calculus and statistics and taught calculus and statistics in a mathematics lab. As a graduate student, I was a teaching assistant for the introductory course in computer science for new Ph.D. students. I ran the mentor program for new Ph.D. students in the 1999-2000 and 2000-1 academic years. In addition, I have acted as a mentor in programs run by the National Science Foundation and the Office of Naval Research. During my PhD work, I supervised a number of students, including other Ph.D. students, Masters students and undergraduate students. As an adjunct professor, I am currently supervising 2 PhD students and co-supervising a third. I recently hosted a visiting PhD student from Denmark for 8 months. I am also actively involved in supervising undergraduate students – I am currently supervising a dozen students from UC Berkeley, and am involved in hosting students through the national CRA mentor program and Berkeley's SUPERB (NSF REU program for historically underrepresented minority undergraduates from other universities), URAP and URO programs (Berkeley research programs for undergraduate students). I actively involve undergraduate students in my research and have co-written a number of papers with them, including four of the papers listed below.

Service:

I am an active member of my research community, both in the areas of human-computer interaction and in ubiquitous computing. I have been a member of the ACM UIST (User Interface and Software Technology) program committee once, the UBICOMP program committee twice and was the co-chair of this year's UBICOMP program committee. I am currently serving on the Pervasive Computing and Graphics Interface program committees this year. I was the ICMI 2003 Registration Chair and the CHI 2003 Demonstrations Co-Chair. I serve as one of six co-editors of the Springer-Verlag published Personal and Ubiquitous Computing journal. I regularly review papers for CHI, UIST, UBICOMP, IEEE Pervasive and have reviewed papers for CSCW and ACM ToCHI and ACM ToSEM.

I am a member of the Intel Research Council, an Intel group of technical experts that awards university research grants to support research in key research areas. In particular, I serve on the User Interface sub-committee.

Selected Publications:

1. M. Ames, C. Bettadapur, A.K. Dey and J. Mankoff. *Healthy Cities Ambient Displays*. Poster in Proceedings of UBICOMP 2003, 5th International Conference on Ubiquitous Computing, pp. 159-160. October 12-15, 2003.

2. L. Barkhuus and A.K. Dey. *Location-based Services for Mobile Telephony: A Study of Users' Privacy Concerns*. Proceedings of INTERACT 2003, 9th IFIP TC13 International Conference on Human-Computer Interaction. September 1-5, 2003.

3. L. Barkhuus and A.K. Dey. *Is Context-aware Computing Taking Control Away From the User? Three Levels of Interactivity Examined*. Proceedings of UBICOMP 2003, 5th International Conference on Ubiquitous Computing, pp. 149-156. October 12-15, 2003.

4. C. Beckmann and A.K. Dey. *SiteView: Tangibly Programming Active Environments with Predictive Visualization*. Technical Report IRB-TR-03-019, Intel Research Berkeley, July 8, 2003. Shortened version as a Poster in Proceedings of UBICOMP 2003, 5th International Conference on Ubiquitous Computing, pp. 167-168. October 12-15, 2003.

5. A.K. Dey, D. Salber and G.D. Abowd. *A Conceptual Framework and a Toolkit for Supporting the Rapid Prototyping of Context-aware Applications*. Anchor article of a special triple issue on context-aware computing. Human-Computer Interaction (HCI) Journal 16(2-4). pp. 97-166. 2001. Also published separately by Lawrence-Erlbaum as an edited book in January 2002, ISBN 0805896856.

6. A.K. Dey, J. Mankoff, G.D. Abowd and S.A. Carter. *Distributed Mediation of Ambiguous Context in Aware Environments*. Proceedings of UIST 2002, Fifteenth Annual Symposium on User Interface Software and Technology, CHI Letters 4(2), pp. 121-130, October 27-30, 2002.

7. A.K. Dey, R. Hamid, C. Beckmann, I. Li and D. Hsu. *a CAPpella*: *Programming by Demonstration of Context-Aware Applications*. To appear in CHI 2004.

8. W.K. Edwards, V. Bellotti, A.K. Dey and M. Newman. *Stuck in the Middle: The Challenges of User-Centered Design and Evaluation for Middleware*. Proceedings of CHI 2003, ACM Conference on Human Factors in Computing Systems, CHI Letters 5(1): 297-304, April 5-10, 2003.

9. S. Lederer, A.K. Dey and J. Mankoff. *A Conceptual Model and a Metaphor of Everyday Privacy in Ubiquitous Computing Environments*. Technical Report UCB-CSD-02-1188, Computer Science Division, University of California, Berkeley and Technical Report IRB-TR-02-017, Intel Research Berkeley, July 30, 2002.

10. S. Lederer, J. Mankoff and A.K. Dey. *Who Wants to Know What When? Privacy Preference Determinants in Ubiquitous Computing*. Short Talk in the Extended Abstracts of CHI 2003, ACM Conference on Human Factors in Computing Systems, pp. 724-725, April 5-10, 2003.

11. S. Lederer, J. Hong, A.K. Dey and J. Landay. *Personal Privacy Through Understanding and Action: Five Pitfalls for Designers*. Submitted to Journal on Personal and Ubiquitous Computing.

12. J. Mankoff, A.K. Dey, G. Hsieh, J. Kientz, M. Ames and S. Lederer. *Heuristic Evaluation of Ambient Displays*. Proceedings of CHI 2003, ACM Conference on Human Factors in Computing Systems, CHI Letters 5(1): 169-176, April 5-10, 2003.

13. T. Matthews, T. Rattenbury, S. Carter, A.K. Dey and J. Mankoff. *A Peripheral Display Toolkit*. Technical Report UCB-CSD-03-1258, Computer Science Division, University of California, Berkeley, October 22, 2003 and Technical Report IRB-TR-03-018, Intel Research Berkeley, July 8, 2003.

14. A. Newberger and A.K. Dey. *Designer Support for Context Monitoring and Control*. Technical Report IRB-TR-03-017, Intel Research Berkeley, July 8, 2003. Submitted to Pervasive 2004.

15. T. Sohn and A.K. Dey. *iCAP: An Informal Tool for Interactive Prototyping of Context-Aware Applications*. Interactive Poster in the Extended Abstracts of CHI 2003, ACM Conference on Human Factors in Computing Systems, Orlando, FL. pp. 974-975, April 5-10, 2003.