When Computers Fade … Pervasive Computing and Situationally-Induced Impairments and Disabilities

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Abstract

Since Weiser introduced his vision of ubiquitous computing, computing devices have become lighter, smaller, cheaper, and more powerful. At the same time, pervasive computing and the concept of context have attracted significant attention, with the goal of supporting the use of computing devices anywhere, anytime, as computers fade into the environment. While there has been some success inferring the users' intensions, reliably understanding users' general goal remains a significant challenge. Using limited context information, such as location, can be useful, but the benefits are limited. Context is more than location. As computers are embedded into everyday things, the situations users encounter become more variable. As a result, situationally-induced impairment and disabilities (SIID) will become more common and user interfaces will play an even more important role. Recent understandings on context suggested the importance of applications themselves as parts of the whole context space. This article will explain and discuss the characteristics of SIID under a three-dimension (human, environment, and applications) context model. We suggest integrating information from all dimensions to have a whole picture of context. More studies are needed to understand the relationship among different dimensions, and to help design effective context-aware applications overcoming SIID.

1 Introduction

Twelve years ago, Weiser introduced his vision of ubiquitous computing as the trend for the 21st century (Weiser, 1991). He imagined a world where people used computers without noticing their existence because they were seamlessly integrated into the environment. Computers would be everywhere, would infer intent, and many would not even be noticed. As the 21st century begins, we find ourselves in a world where computers are smaller, more mobile, more powerful, and less expensive. Computers are being integrated into the environment such that they are not noticed, there has been some success inferring intent, but many computers are still quite identifiable as technological support for the activities we are engaged in. Clearly, we are making progress toward Weiser's vision. Examples include augmenting the functionality of everyday objects such as coffee cups via embedded sensors and circuits (Beigl, Gellersen, & Schmidt, 2001) and facilitating guided tours by integrating positioning devices throughout buildings (Abowd et al., 1997).

While we have made progress toward Weiser's vision, two of the key terms he used to describe this vision continue to evolve. Today, *environment* has, to a large extent, been replaced by *context*.

It seems that *environment* often caused people to focus on the physical space in which the technology was being used, while *context* is seen as expanding the focus to include not only the physical space, but also aspects of the social situation that may influence the use of technology. Currently, context-aware systems are the focus of significant research. At the same time, *pervasive computing* seems to be replacing *ubiquitous computing* to emphasize the way these devices permeate everyday activities. Everyday artifacts may look the same, but today they often include some form of computing technology which makes decisions and shapes the user's activities. Before a call is connected, recipient's phone can inform the caller if a voice message is preferred rather than a phone call (Gellersen, Schmidt, & Beigl, 2002). As Weiser envisioned, computers are beginning to vanish into our everyday lives.

Examples include multiple attempts to create smart environments within buildings. Unfortunately, difficulty inferring the user's intent can lead to inappropriate results (Bellotti & Edwards, 2001). An individual can be greeted by with personalized message when they enter an office, phone calls can be forwarded as an individual moves from room to room, and printing requests could be routed to the nearest printer for quick pick-up. While each of these scenarios could provide benefits, they can also prove problematic if the individual's goals are not adequately understood. Personalized greetings can become a disturbance if they do not provide useful information or if the person is using a mobile phone when entering the room. Automatic forwarding of telephone calls may be inappropriate if the person is going into a meeting. The "nearest" printer may not be in a convenient location when the document is finally printed.

As researchers continue to investigate techniques for inferring the user's goals, applications such as those described above will become more effective. However, focusing on environment at this level can only provide limited benefits. Many efforts to develop context-aware technologies pay little attention to the interactions that will still occur. Even as computing devices become embedded in the environment, and computers become more invisible to their users, users will still be interacting with some combination of hardware and software. These technologies may look different, and involve new interaction techniques, but they will still require input from users, generate results that are intended to benefit these users, and perhaps even present information directly to the users. As a result, information technologies will continue to play an important role in effective and efficient interactions even as technology becomes smaller, more mobile, and increasingly embedded into the environment. Interestingly, as these changes occur, the environments in which people use these technologies become more variable. This suggests that additional research is needed that focuses on understanding the difficulties users experience when interacting with information technologies in these increasingly complex environments. The concept of SIID (Sears & Young, 2003) is suggested as a framework for addressing these issues.

2 Situationally-Induced Impairments and Disabilities

According to the International Classification of Functioning, Disability and Health (ICIDH-2), impairment refers to a loss or abnormality of body structure or function and disability refers to difficulties an individual may have in executing a task or action. Although these definitions originate in the healthcare community, the concepts also apply in the context of human-computer interactions, especially when environmental factors are considered. For example, the absence of a limb is a physical impairment that may, depending on the input technologies available, result in computer-oriented disabilities. Hands-busy situations can result in similar disabilities, depending on the input technologies that are available. Similarly, a variety of health conditions, or a noisy environment, can result in disabilities associated with speech-based interactions with computers.

Both the work environment and the activities the individual is engaged in can lead to SIID. For example, a paramedic may be busy providing medical care to a patient in a moving ambulance. At the same time, the paramedic must document patient conditions and treatment so this information can be given to caregivers upon arrival at the hospital. The vibration from the moving vehicle as well as the demands of providing appropriate health care degrades the paramedic's ability to interact with physical input devices. The siren and road noise hinder the use of speech-based interactions. These SIID make interactions between users and computing devices more difficult. Other factors, including temperature, lighting, demands for the user's attention, and stress can also adversely affect an individual's ability to interact effectively with computing technologies.

While we intentionally draw an analogy to difficulties that may be experienced due to health conditions, we also explicitly acknowledge that SIIDs are different in that they tend to be temporary and dynamic. Individuals typically develop strategies to overcome health-related disabilities, but the temporary and dynamic nature of SIID makes this more difficult. A strategy may be effective at one moment and ineffective at the next. As a result, information technologies that are aware of the difficulties users may experience as a result of the current environment and tasks are increasingly important: different strategies can be presented to users, alternative interaction techniques can be supported, or the way input is processed can be adapted.

3 Defining Context (and the Role of SIID)

Schmidt et al. (1999) proposed a three dimensional model to describe the concept of "context" that explicitly separated activities, users, and the environment. More recently, Dey et al. (2001) provided a broad definition that includes "any information that can be used to characterize the situation of entities (i.e. whether a person, place, or object) that are considered relevant to the interaction between a user and an application, including the user and the application themselves". Schmidt's model provides an effective high-level representation of context, but many details were not provided leaving the relationship among different dimensions vague and largely unexplored. Dey's definition explicitly encompasses all of the information that could prove useful for context-aware technologies. It also represents the first time that applications were identified as an entity at the same level as the users.

While broad definitions have been offered, rather limited definitions of context tend to be employed in practice and the definitions that are employed tend to focus on the underlying technologies as opposed to how the difficulties users may encounter when interacting with these technologies. Location is perhaps the most studied aspect of context. Examples include the Active Badge system (Want et al., 1992), a coupon delivery service (Duri et al., 2001), and a tour guide system (Cheverst et al., 2000; Pascoe, 1997). While several groups (Brown, Bovey, & Chen, 1997; Dey, 1998) have stressed that there is more to context than location, research on context-aware has continued to emphasize the physical environment. Of particular interest is the fact that few researchers have focused on how the users and their activities factor into the definition of context. One effort that did explicitly focus on the users' activities resulted in the concept of a minimal attention user interface (MAUI) (Pascoe, Ryan, & Morse, 2000). This concept was illustrated using applications that supported an ecologist's observations of giraffes. These applications address some SIID, such as those that result from eyes-busy tasks, and represent one of the few situations where the users' interactions were the primary focus of the research. Figure 1 represents a combination of the 3D model proposed by Schmidt et al. and the definition proposed by Dey et al., that separates contextual information into three categories: human, environment, and application. The human dimension addresses the characteristics of the user (e.g., identity, preference, biophysiological conditions, emotional state), current social issues (e.g., existence of other people, social interactions), and users' current activities (e.g., walking, filling out a form, looking for a phone number, following a map). The environment dimension includes location, physical conditions (e.g., lighting, noise, temperature, speed), and the infrastructure (e.g., embedded devices, sensors, communication protocols). The application dimension includes the available functions (e.g., backlight control, font size adjustment, zoom function) and input/output channels (e.g., touch screen, voice command, gesture recognition, audio output, vibration). While most research continues to focus on a single dimension, the concept of SIID can only be addressed if the cumulative effects of all three dimensions are considered.

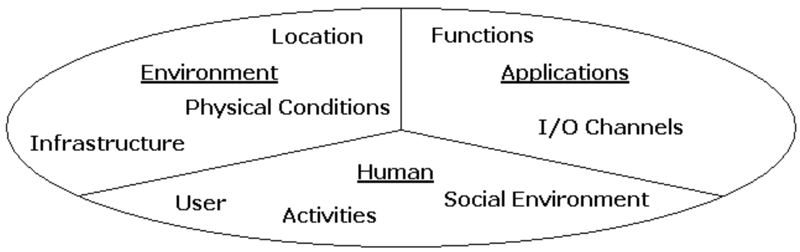

Figure 1: 3D Context Space

For example, when the user is attempting to complete a task, the application dimension defines how the task can be completed (e.g., speech input, stylus input, physical keyboard). The environmental dimension may make one or more of the alternatives more or less attractive (e.g., speech input is not effective in a noisy environment). Similarly, the human dimension can alter the efficacy of various solutions (e.g., speech impairments may preclude speech-based interactions; physical impairments may hinder the use of stylus-based input). SIID can only be addressed if all three dimensions are understood and, more importantly, the interactions among these dimensions are understood. Clearly, some of this understanding is the responsibility of the user, but the information technologies can also contribute to this process.

Users can recognize certain aspects of the context and adapt. They can stop walking if motion causes difficulties entering information, mute their phone if the conversation hinders speech-based input, or even switch to a different input device. The user may be able to turn on additional lights, turn off a radio, or move indoors if necessary. However, the context may also limit the user-based adaptations that are feasible. For example, a paramedic must continue with their primary task of providing healthcare even if this interferes to with their record keeping activities. Similarly, sensors can allow technology initiated adaptations to accommodate environmental issues and user activities (Hinckley et al., 2000). As background noise increases, speech interactions can be enhanced using noise filtering algorithms. If the background noise becomes too loud, speech recognition can be disabled and the input can be digitized for subsequent processing. If the user is moving, stylus-based input can be debounced. If the movement becomes such that debouncing is no longer effective, alternative forms of input could be suggested. If the lighting is insufficient, contrast can be increased or backlighting can be turned on.

4 Conclusion

While current definitions of context include the necessary information, the interactions among the dimensions have not been adequately explored. The concept of SIID provides a framework for this exploration within the larger framework of context-aware computing. SIID highlight the importance of understanding all three dimensions, how these dimensions interact, how users adapt, and how technology-based adaptations can facilitate more effective solutions that reduce errors and speed interactions. As computers continue to fade, users will continue to interact with these technologies, but these interactions will become more subtle, the environments will become more complex, and the interactions among the human, environment, and application dimensions will become even more important.

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6 References

Abowd, G. D., Atkeson, C. G., Hong, J., Long, S., Kooper, R., & Pinkerton, M. (1997). Cyberguide: A mobile context-aware tour guide. *ACM Wireless Networks*, 3, 421-433.

Beigl, M., Gellersen, H.-W., & Schmidt, A. (2001). MediaCups: Experience with Design and Use of Computer-Augmented Everyday Artefacts. *Computer Networks*, 35 (4), 401-409.

Bellotti, V., & Edwards, K. (2001). Intelligibility and Accountability: Human Considerations in Context-Aware Systems. *Human-Computer Interaction*, 16 (2-4), 193-212.

Brown, P. J., Bovey, J. D., & Chen, X. (1997). Context-aware applications: From the laboratory to the marketplace. *IEEE Personal Communication*, 4 (5), 58-64.

Cheverst, K., Davies, N., Mitchell, K., & Friday, A. (2000). Experiences of developing and deploying a context-aware tourist guide: The GUIDE project. In *Proceedings of the MOBICOM Conference*, 20-31.

Dey, A. K. (1998). Context-aware computing: The CyberDesk project. In *Proceedings of the AAAI '98 Spring Symposium on Intelligent Environments*, 51-54.

Dey, A. K., Abowd, G. D., & Salber, D. (2001). A Conceptual Framework and a Toolkit for Supporting the Rapid Prototyping of Context-Aware Applications. *Human-Computer Interaction*, 16, 97-166.

Duri, S., Cole, A., Munson, J., & Christensen, J. (2001). An approach to providing a seamless end-user experience for location-aware applications. In *Proceedings of the WMC*, 20-25.

Gellersen, H. W., Schmidt, A., & Beigl, M. (2002). Multi-sensor context-awareness in mobile devices and smart artifacts. *Mobile Networks and Applications*, 7 (5), 341-351.

Hinckley, K., Pierce, J., Sinclair, M., & Horvitz, E. (2000). Sensing Techniques for Mobile Interaction, ACM Symposium on User Interface Software & Technology, 91-100.

Pascoe, J., Ryan, N., & Morse, D. (2000). Using while moving: HCI issues in fieldwork environments. *ACM Transactions on Computer-Human Interaction*, 7 (3), 417-437.

Schmidt, A., Aidoo, K. A., Takaluoma, A., Tuomela, U., Laerhoven, K. V., & Velde, W. V. d. (1999). Advanced Interaction in Context. In *Proceedings of the HUC*, 89-101.

Sears, A., & Young, M. (2003). Physical Disabilities and Computing Technologies: An Analysis of Impairments. In J. A. Jacko and A. Sears (Eds.), *Human-Computer Interaction Handbook* (pp. 482-503).

Want, R., Hopper, A., Falcao, V., & Gibbons, J. (1992). The Active Badge Location System. *ACM Transactions on Information Systems*, 10 (1), 91-102.

Weiser, M. (1991). The Computer for the 21st Century. *Scientific American*, 265, 94-104.