Creating Distributed Support Systems to Enhance the Quality of Life for People with Cognitive Disabilities

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Abstract. This paper presents an envisioned use of pervasive computing to enhance the quality of life for people with cognitive disabilities and their caregivers. We briefly describe common circumstances that prevent people with cognitive disabilities from achieving the level of independence they desire. We then present a model of distributed support that can help people to safely live more independent and integrated lives. We conclude by describing the MAPS-LifeLine prototype, which shows how pervasive computing environments can be utilized to provide such support.

1   Using of pervasive computing in healthcare

It is our view that the central goal of healthcare is to preserve and increase the quality of life for both the patient and their circle of supporters. Environments enhanced with pervasive and ubiquitous computational resources can encourage individual independence while affording the delivery of medical and daily living support in the most appropriate, unobtrusive, and effective manner possible. We envision leveraging emerging ubiquitous computing technologies to support a more integrated, independent, and secure life for people with cognitive disabilities (hereinafter referred to as "clients") and their caregivers.

2   Current Work

In order to explore how technology could positively impact the quality of life for people with cognitive disabilities, we conducted a series of site visits to assisted living group homes and interviewed subject-matter experts. One of the first things we noticed was the variety of low-tech cognitive aids that were being used in the field. For example, picture books were compiled to show clients the steps required to complete a task. These were used with some effectiveness, but their passive nature was a major drawback (i.e., they could not react to current contextual conditions). In survey-

ing other existing solutions for task support we found several computational variations of these picture books (e.g., see Visions [1] and PocketCoach [5]). A common advantage of these computational artifacts was their ability to combine voice instruction with picture prompts. Although the increased modality provided by these systems was as improvement, there was still a lack context-awareness. A second thing we noticed during our site visits was that caregivers were a scarce resource. Furthermore, higher-functioning clients often desired more integration with their community, but were limited by the availability of their caregivers, who were often responsible for other, lower-functioning clients. Caregivers, who were responsible for the safety of their clients, found it difficult to balance their responsibilities with their clients' desires. We saw an opportunity to use of ubiquitous computing to provide clients with greater autonomy, by providing clients with context-sensitive task support and caregivers with remote supervision and intervention capabilities.

MAPS-LifeLine: An Active Distributed Support System. The social environments in which people with cognitive disabilities live and work are unique from the perspective of cooperative work practices and distributed cognition. As in most group tasks, the knowledge required to complete a task is shared by people and artifacts; however, this is more pronounced in activities involving caregivers and clients because there is typically a significant disparity in reasoning and problem solving abilities. This disparity can be overcome if clients can successfully leverage their own abilities as well as the abilities of their caregivers. For example, if a client performs tasks that require a moderate level of indoor navigation, a distributed socio-technical system that utilizes ubiquitous computing and communication technologies can help provide the cognitive and social support that the client needs. A particularly important characteristic required to support such a task is the ability to react to changing, and perhaps unpredicted, circumstances. To illustrate this example, consider a client performing a job such as intra-building mail delivery. If the client becomes lost or confused, an active distributed support system can detect this and moderate an intervention by a human or computational agent, thus facilitating error recovery and task completion. This is a task that cannot be well supported by a passive artifact such as a picture book.

In order to design such a distributed support system we first worked with subject-matter experts to create a scenario [8], which we then used as a guidepost for our design. Guided by our scenario and also by a distributed cognition framework [10], we developed two moderately coupled prototypes: the Memory Aiding Prompting System (MAPS) [2], a mobile wireless context-aware prompting system that runs on a hand-held device; and LifeLine [7], a remote monitoring and intervention system that caregivers can use to supervise and support their clients in common tasks for living and working. Together these systems (hereinafter referred to as MAPS-LifeLine) create a powerful synergy that allows caregivers to interactively support their clients in an untethered and unobtrusive way [4].

Error Recovery in a Complex World. The use of prompting systems can give clients greater independence [5]. However, with greater independence comes greater exposure to unfamiliar and potentially dangerous situations. Prompting systems that support only simple linear tasks are not equipped to support clients in dynamic settings. Ubiquitous presence of computation allows for the development of more context-aware systems that are better equipped to operate in dynamic settings.

In our model, a client uses scripts to complete tasks that he or she can otherwise not reliably complete. Caregivers use the MAPS Script Editor to assemble a series of linked pairs of visual and auditory prompts. The caregiver creates a plan in the form of a script, but acknowledge the possible need to provide guidance or alter the plan in mid-execution. The caregiver facilitates successful task completion and acts like an air traffic controller, guiding the client when necessary. This requires that they: 1) know the plan that is being executed by the client, 2) know how the client is performing with respect to that plan, and 3) be able to provide the support necessary to minimize deviations from the plan. The LifeLine application, using data provided by the MAPS prompter and external sensors, provides information to the caregiver about the status and immediate needs of the client. The caregiver can actively monitor a client's progress; however, as confidence in a client's ability increases, support can be mediated in a "need to know" manner (e.g., sending Short Message System (SMS) messages to a caregiver when certain error conditions arise).

The MAPS-LifeLine system uses a dynamic, multi-tiered approach to error detection and intervention. The MAPS Script Editor provides a wizard that helps caregivers set up default error detection and correction routines for each client. This affects the type of intervention that is provided when certain classes of errors are encountered. In this approach, the intervention strategy is based on the characteristics of the client and the nature of the error [3]. In some cases the client will immediately be connected to a caregiver; however, for a higher functioning, more experienced client, the required support could be in the form of a computer-generated intervention.

MAPS-LifeLine implements error detection by using a combination of internal state monitoring and sensor technologies. While scripts are running metadata about task step timing and sequence provide cues that help determine if the user is "off track." In addition, the LifeLine conduit, which runs on the handheld device, transmits GPS and other sensor data (e.g., see MANTIS [9] and Mobility for All [6]) to the LifeLine server. This is used to match a client's actual position with expectations specified by the metadata in the MAPS script. By using these cues to detect an error in context, MAPS and LifeLine work in concert to provide a tiered, escalating, and user appropriate set of error correction strategies.

Robustness and Fail-Safe Considerations During our interviews with caregivers in group homes, concern for safety and accountability were among the most common issues that were raised. In considering these issues as well as the analyses of potential situations they might encounter, we identified the following vulnerabilities associated with the physical separateness.

Caregivers expressed concern that the wireless connectivity was a weak link in the system. To address this concern, MAPS-LifeLine implements two fail-safe strategies.

Redundant wireless connectivity methods are used on the hand-held (i.e., Wi-Fi and wireless PPP dialup). Polling algorithms are used on the server where a stable TCP-IP connection is assumed. Polling serves two purposes. Associated with each step in a task sequence is a time-to-complete threshold. If this threshold is reached before MAPS signifies the beginning of the next task step, LifeLine will send an SMS message to the caregiver. This approach permits the trapping of multiple error types, such as: (1) the client has trouble completing a task step, (2) MAPS loses and cannot re-establish a TCP-IP connection, or (3) the hand-held device is physically damaged (e.g., as a result of being dropped) or lost

3   Expectations Towards the Workshop

We are interested in exchanging perspectives on using ubiquitous technologies to create context-aware applications that support help people to perform common activities of daily living. We hope to share what we have learned in this respect and also to understand and adapt the work of others so that we may build more effective systems.

We have been exploring the technical issues involved in creating "smart homes", but are especially interested in cognitive and social issues that affect the design such systems. We would be interested in discussing others' experiences on similar projects. In particular, we are interested in the use of sensor data to create more intelligent systems that are less reliant on explicit user input.

4   The Authors' Research Activities

The authors have been working on the Cognitive Lever (Clever) project since 1999. The mission of the CLever project is to provide computationally enhanced environments to assist people with a wide range of cognitive disabilities and their support community. CLever is a research project of the Center for LifeLong Learning and Design (L^{3}D) at CU-Boulder, which for the last 15 years has focused on Intelligence Augmentation (IA) approaches with the objective of complementing and empowering human capabilities.

We believe that individuals can—and in some cases must—follow very different learning paths. Our goal is to respond to that challenge by creating environments that match individual needs and learning styles. It is our hope that people at all cognitive levels will greatly profit from the conceptual frameworks and systems that we are developing. This work is funded by the Coleman Institute for Cognitive Disabilities.

5   A Short Biography of the Authors

Stefan Carmien received a BS in Computer Science in 1992 from the University of Colorado, Boulder and has been a graduate student in the Center for LifeLong Learning

and Design since 1999, receiving an MS in 2001. His research interests include designing assistive technology for people with cognitive disabilities from an Artificial Intelligence and Human-Computer Interaction perspective as well as socio-technical approaches to computer-supported collaboration. He is currently working on a PhD in Computer Science with a certificate in cognitive science from the Institute of Cognitive Science at the University of Colorado, Boulder. He has been part of the Cognitive Lever project since 1999 and is currently developing the Memory Aiding Prompting System.

Andrew Gorman received a BS in Computer Science in 1988 from Kean University and an MS in Computer Science in 1998 from the University of Colorado, Boulder. Since then he has been a researcher at the Center for LifeLong Learning and Design (L^{3}D) and a member of the Institute of Cognitive Science at the University of Colorado, Boulder. His research interests include Human-Computer Interaction, User Modeling, and Computer-Supported Collaboration. He is a founding member and co-director of the Cognitive Levers project. He is also the lead developer of the LifeLine system, investigating the application of ubiquitous computing technologies in synchronous distributed support systems.

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