Adaptive Interfaces for Home Health

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Abstract. Technology for home health applications offers great promise for helping patients and their families manage their health and maintain independence. However, user interface issues are often the greatest barrier to these systems being used. The focus of our research has been to develop methods for measuring cognitive performance through the unobtrusive monitoring of users' interactions with the computer. This data is useful for both measuring cognitive changes as an important health indicator, but also for dynamically adapting the user interface of the various computer applications based on this information to better meet the needs of individual users.

1 Introduction

As more and more of our health care resources are dedicated to chronic diseases and conditions associated with aging, the model of medical care is changing from clinic and hospital-based reactive care to long-term management of health in coordination with patients and their families in the home. Scientists and engineers have an opportunity to influence this direction by focusing on technologies to improve the ability of patients and their families to manage their health at home. Most current uses of home health technology have included a variety of approaches for chronic disease management and systems to assist home health nurses. Disease management systems usually target a single disease, monitoring key physiological parameters and conveying the information to clinicians. However, in an aging population, most patients have more than one chronic disease, several medications, and quality of life issues that loom larger than a narrow definition of medical care. Care that addresses these multiple factors must be coordinated and integrated into patients' routine daily activities.

Our strategic position for using technology to improve health is to focus on the health management that occurs in patients' homes under the primary direction of patients and their families. Some key issues of importance in this effort are

- Focus on holistic quality of life as opposed to single medical findings
- Integration of health goals and behaviors into routine daily activities

- Usability, with a focus on adaptive tailored user interfaces

1.1 Quality of Life as a Measure of Health

Most of the medical models used in home health applications focus on a small set of physiological parameters (e.g., blood glucose, weight, blood pressure). However, with an aging population with multiple chronic diseases, it has been clear that the emphasis in health care needs to be more holistic and include the full spectrum of dimensions of quality of life. For example, social and emotional aspects of health have a profound effect on life expectancy, medical care utilization, and level of independence. Technological solutions that facilitate communication with remote family members and caregivers can make a substantial contribution to health management in the home. These approaches improve both quality of life and have the potential to reduce health care costs by preempting costly emergency visits and early transitions to nursing homes. A key component of our research plan has been to expand medical monitoring to include aspects of cognition as part of overall quality of life.

1.2 Integration of Health Technologies into Routine Daily Activities

Many current home health technologies require patients to perform monitoring activities at a specific time and place with equipment dedicated to the process. The primary barrier to home health activities has been patients' adherence to clinical health management goals. Although much is known about guidelines and principles for health behavior change, this knowledge is rarely used in home health technology interventions. Automated "coaching" using technology for "just-in-time" communication prompts, feedback, and social support is a useful technique for improving the success of home health interventions. A key feature of successful home health interventions is that they be multi-faceted and incorporate health-related activities into other routine daily activities. In addition, monitoring techniques that are relatively automated and unobtrusive are much more likely to be successful. This often means that the data is more noisy and requires more sophisticated algorithms for inferring patient state, but the data will be more continuous and not dependent on patient adherence for success.

1.3 Adaptive User Interfaces

Probably the most significant barrier to the successful use of technology for home health applications is the difficulty in developing suitable user interfaces for older patients with many potential chronic conditions that affect mobility, cognition, and self-confidence. Our overall approach is to keep interfaces as simple and clear as possible. However, offerings of help, hints, and recommended tasks should depend on a robust user model that includes a measure of cognitive ability. Our research focus in this area has been to create measures of cognitive performance for a variety of computer interactions and then to adapt further interfaces with the user on this estimate.

2 Sample e-Health Project: Monitoring Computer - User Interactions to Adapt Interfaces and to Detect Cognitive Changes

Our research in monitoring users' interactions with computers has focused on both the detection of cognitive changes that can be used for health management as well as for adapting computer interfaces to individual users with varying cognitive capabilities. In addition to monitoring speed and accuracy on routine tasks, such as email and Web browsing, we have developed or adapted computer tasks to provide us with specific measures of cognition. Our approach has been to create applications that are

- designed to relate to improving independence and activities of daily living
- designed to be entertaining and compelling so that users are more likely to use them on a routine basis
- designed to be unobtrusive and require not additional input from the users
- tailored to individual users' abilities, computer skills and current cognitive state
- designed to measure performance at close to the 50% success rate so that the measure is most sensitive and also most engaging for the user
- designed to use multiple inputs and features from a variety of tasks to infer cognitive abilities of the user

The Intel Corporation recently funded researchers at Oregon Health & Science University to do an exploratory study of how elders' interactions with computers could be used to infer cognitive state and to detect changes in cognitive performance. In conjunction with the Spry Learning Company, we first performed a needs assessment to determine which computer applications and capabilities would be most engaging and useful for older adults. We conducted a set of focus groups with residents in the Calaroga Terrace Residential Facility in Portland, Oregon to determine the general interests and activities of the residents, both in general and with regard to computer use. Email, Web browsing, and computer games were seen as the most important and frequently used applications. We also were able to ascertain guidelines and suggestions for user interfaces, with the most common request being to "keep it clear and simple" with a minimal learning curve. Most of the computer users enjoyed playing computer games. By far, the most popular was the computer game FreeCell. This is a version of the card game Solitaire that requires strategic planning. People in the focus groups reported that they played FreeCell both for enjoyment and to keep their minds sharp. When we asked about our plan to develop a variety of other computer games and tasks to monitor cognitive performance as well, the general feedback showed great interest and willingness to trade off entertainment value for a possible improvement in cognition.

Based on the feedback from our needs assessment, we selected the computer game FreeCell as our first test case for monitoring user interactions to determine cognitive performance. This particular game incorporated many aspects of cognition that relate to maintaining independence in the home (e.g., short-term memory, strategic planning, etc.). In addition, this was an activity that the residents enjoyed and were willing to play several times a day. We developed a research version of FreeCell that included an automated solver, so that we could compare user performance to an optimal standard. In this exploratory study, we develop algorithms to detect trends in cognitive performance, and be able to present games at the appropriate difficulty level for each user.

2.1 A Sample Framework for Characterizing Task Difficulty and User Performance

In our adaptation of the FreeCell computer game, user interactions are monitored and compared with "standard" performance as defined by an automated solver. The initial pilot version of our adapted version of FreeCell uses an automated developed by Tom Holroyd and publicly available via the Web by downloading "patsolve" at http://members.tripod.com/professor_tom/archives/. This is an ANSI C program that automatically solves FreeCell with a near optimal solution. (There are no known optimal solvers for FreeCell.) Our research contribution has been to use the data from this solver (number of card moves to complete solution) to define the difficulty of the game at any point in time. This difficulty metric also defines whether an individual move by a user (or a series of moves) is consistent with winning the game with the minimal number of moves. Appropriate moves (or sequences of moves) should reduce the difficulty of the game state. Our measure of cognitive performance for this particular computer game/task, p_g, is based on several variables:

- Game difficulty, $d(g,i)$ is the automated solver's calculation of the number of moves required to complete game g on the *ith* move of the user.
- User performance for a particular move, $p(g,i) = d(g,i\text{-}1) - d(g,i)$; This measure is positive if the game difficulty is reduced by the user's move.
- The outcome of the game, *outcome* = *win* if the game was won, *quit* if the user closes the game while the game is still winnable and there are cards left to play, *loss* if the game was completed to a state where it was unwinnable.
- Overall game difficulty, $d(g,0)$ = the difficulty of game g in its initial state (i = 0)
- Number of moves to completion of session, m = the number of moves the user took to either win the game, lose the game, or the number of moves used before quitting.
- Time to completion of session, t

We must then filter the resulting performance values, removing normal daily variation and learning effects. The final algorithm is design to detect long-term sustainable changes in cognitive performance. The subsequent FreeCell games presented the individual user are then matched to the cognitive performance level of the user.

2.2 Further Development of Computer Tasks and Games

We are also developing a series of computer tasks (framed as games) to measure divided attention, short-term memory, long-term memory, planning capabilities, hand/eye coordination, and spatial awareness. These computer tasks will also have algorithms that compare user performance with an automated solver's optimal performance to create a metric of one component of cognitive ability. An important component of this development involves adapting the level of difficulty of the computer games and tasks to the appropriate level of the user, as measured by performance on previous interactions. We choose the game or task difficulty to present in a way that both optimizes the user experience and allows us the most sensitive measure of performance. With regard to user experience, we want to present games or tasks that the user can successfully accomplish approximately 50% of the time. This keeps people engaged and challenged, without becoming overly discouraged. With regard to performance measurement sensitivity, a 50% success rate provides the greatest performance information per game or task. If the user is almost always successful or if the user almost always fails, it is much more difficult to detect changes in performance.

3 Conclusion

Unobtrusive monitoring of users' interactions with computers offers a rich data source for models of cognitive performance. Our ability to predict cognitive abilities of users yields important health data for patients and caregivers, but also provides us with a sound metric for adaptive computer interfaces to the abilities of individual users.

About the Authors

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