Intelligent Ubiquitous Computing to Support Alzheimer's Patients: Enabling the Cognitively Disabled

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ABSTRACT

Assisted Cognition systems provide active cognitive aids for people with reduced memory and problem-solving abilities due to Alzheimer's Disease or other disorders. Two concrete examples of the Assisted Cognition systems we are developing are an ACTIVITY COMPASS that helps reduce spatial disorientation both inside and outside the home, and an ADL PROMPTER that helps patients carry out multi-step everyday tasks.

Keywords

medical applications, context-aware computing, aging in place, artificial intelligence, proactive environments

INTRODUCTION

To date computer systems designed to help people suffering from cognitive disabilities due to aging, disease, or accidents have been rare and of limited scope. Recently, however, researchers in ubiquitous computing and artificial intelligence have come together to envision systems that can act as proactive partners in increasing the independence and security of people who have problems of memory, planning, and carrying out tasks of everyday life[7, 1, 5, 4]. A major motivation for developing intelligent caretaking systems is that the growing elderly population in many nations is leading to a crisis of demographics that will bankrupt current human and medical resources. The most common disease, Alzheimer's, currently affects four million Americans; by 2050, the number is expected to rise to 15 million, out of a world total of 80 million.

Both the physical and social environments greatly affect a cognitively impaired person's level of functioning. For example, an Alzheimer's patient may come to rely on the memory, remindings, guidance, and prompts of a caregiver, such as a spouse or other family member [6, 8]. Thus the social environment can provide *active interventions* that extend the patient's ability to handle the challenges of everyday life. But there is a limit to any person's capability to provide such help: physical and emotional 'burnout" of caregivers, often with serious health consequences, is a common phenomena [2].

The goal of Assisted Cognition is to develop computer systems that can provide such *active* assistance to an Alzheimer's patient. In brief, Assisted Cognition systems (i) sense aspects of an individual's location and environment, both outdoors and at home, relying on a wide range of sensors such as Global Positioning Systems (GPS), active badges, motion detectors, and other ubiquitous computing infrastructure; (ii) learn to interpret patterns of everyday behavior, and recognize signs of distress, disorientation, or confusion, using techniques from state estimation, plan recognition, and machine learning; and (iii) offer help to patients through various kinds of interventions, and alert human caregivers in case of danger.

The Assisted Cognition Project is an interdisciplinary effort between the University of Washington's Dept. of Computer Science Engineering, the Alzheimer's Disease Research Center, and the UW Schools of Nursing and Medicine. Industrial partners include Intel Research and Elite Care, whose Oatfield Estates are a living prototype of a ubiquitous-computing enabled residential home for the elderly in Portland, Oregon. The home senses and records nearly all activity going on in or around its campus, including the movements of all residents and staff, operation of all lights and appliances, movement of all doors, *etc.* This enormous and detailed real-world sensor stream provides one of the primary data sources for our project.

THE ADL PROMPTER

A common problem in the early to middle stages of Alzheimer's is a difficulty in carrying out complex tasks, while the ability to perform simple actions is relatively unimpaired [6]. For example, an Alzheimer's patient may be able to perform the individual steps in dressing him or herself, but be unable to recall the proper sequence of actions, *e.g.* that socks go on before shoes.

The ADL PROMPTER is a system that helps guide an impaired individual through the steps of such an "activitiy of daily living" (ADL). Input to the system comes from a sensor network embedded in the home environment. Data from the network (see Fig. 1), together with a rich probabilistic model of how activities are typically carried out, is integrated to create a model that predicts *what the patient is trying to do*.

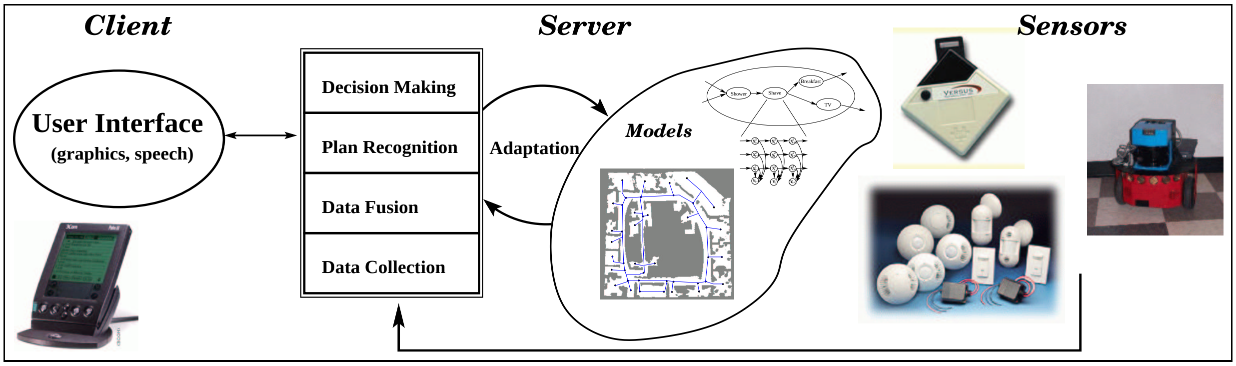

Figure 1: Architecture of Assisted Cognition systems. The server module consists of layers of increasing levels of abstraction. Probabilistic models of sensors and the environment are applied to process noisy sensor data. User activities are tracked using hierarchical Bayesian models. Probabilistic descriptions of these activities help to determine the user's plans and goals, which enable the system to choose which interactions to trigger.

The sensors may include ones for sound, motion, position of objects, movement of doors, operation of appliances, and so on. For example, the system might note that it is morning, and that the patient entered the bathroom and turned on the sink. Some time passes, and the patient remains motionless. The system predicts that the "morning toothbrushing and bathing" activity has begun but become stalled. Finally, the system decides to intervene by verbally prompting the patient to pick up the toothbrush. Note that a prompt is not given unless it is deemed necessary, and prompts are not preprogrammed for certain times of the time.

THE ACTIVITY COMPASS

The ACTIVITY COMPASS is a tool for helping a patient move independently (and safely) throughout his or her community. The compass is based on a client/server architecture where the client handles interaction with the user, and the server stores sensor readings, constructed models, and background information. Our current ACTIVITY COMPASS client is a GPS and wireless-enabled Palm PDA.

The Assisted Cognition differs from an ordinary GPS guidance device in several crucial ways: (1) Instead of requiring the user to manually enter a destination, the system attempts to predict the user's destination based on learned patterns of behavior. (2) The Assisted Cognition can *proactively* engage the user: for example, if it infers that the user is wandering and may be lost, it may suggest that the patient head home by a audible prompt and a simple graphic display (*e.g.*, an arrow pointing in an appropriate direction). (3) The Assisted Cognition can link current data about the user's movements with external environmental information that is relevent to the user's goals.

An example of such external information are bus routes and real-time bus locations (which are available in the Seattle area). The following scenario illustrates how such information could be used: *1. Don is walking toward a bus stop; 2. The system notes that at this time of day Don frequently catches the bus home; 3. Real-time bus information shows that bus leaves in 5 minute, and next one is in an hour; 4. The system predicts Don will miss bus at his current rate of walking; 5. The system decides to intervene by alerting Don to walk faster.*

TECHNICAL COMPONENTS

Both the ADL PROMPTER and ACTIVITY COMPASS are based on a layered architecture (see Fig. 1) linking sensor data to simple behaviors, behaviors to plans and goals, and predictions of the success or failure of those plans to potential interventions. Each layer takes in noisy and uncertain information, abstracts and fuses the data to reduce (but not always eliminate) uncertainty, and passes this higher-level view of the world to the next layer. Feedback from the effects of invention feed back down through the layers, in order to improve the accuracy and effectiveness of the underlying models. More detailed technical discussion appears in [3].

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