easyADL – Wearable Support System for Independent Life despite Dementia

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Abstract
This position paper outlines the easyADL project, a two-year project investigating the possibility of using wearable technology to assist people suffering the dementia disease in performing Activities of Daily Living (ADL). An introduction to the egocentric interaction modeling framework is provided and the Virtual Reality based development methodology is discussed.

Keywords
Design methodology, cognitive prostheses, virtual reality, context awareness, wearable computing.

ACM Classification Keywords
H.1.2 [Models and Principles]: User/Machine Systems---human factors; H.5.1 [Information Interfaces and Presentation (e.g., HCI)]: Multimedia Information Systems---artificial, augmented, and virtual realities; H.5.2 [Information Interfaces and Presentation (e.g., HCI)]: User Interfaces---prototyping; I.2.6 [Artificial Intelligence]: Learning---knowledge acquisition; J.3 [Life and Medical Sciences]: Medical information systems; K.8.m [Personal Computing]: Miscellaneous.

Background
With a continuous increase of progressively older citizens, age-related healthcare is becoming a significant problem both from a humane and economical perspective.

Dementia and Activities of Daily Living (ADL)
Dementia is a collective name for diseases causing dysfunction of nerve cells of which the most common is Alzheimer's disease. Dementia is not regarded as a natural part of aging and affects different individuals differently. Furthermore, the handicap caused by the disease tends to change over time. Typical problems experienced by dementia patients (partially derived from [1]) and examples of ADL are listed in table 1.

Project partners and goals

This project is collaborated by the Dept. of Geriatrics at the University Hospital of Northern Sweden, VRlab at Umeå University, and Dept. of Computing Science, Umeå University.

The main goal of the project is to develop a prototype for a "cognitive prosthesis" (Fig. 1) enabling people suffering from cognitive disorders to perform important ADL in their homes without professional support.

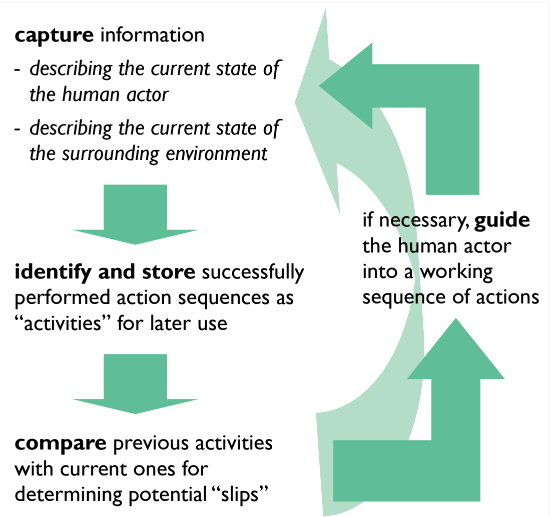

Figure 1. "Cognitive prosthesis" interaction cycle.

- **Geriatric subgoal:** To find out to what extent state-of-the-art computer technology could complement existing care practices.
- **Virtual Reality subgoal:** 1) To determine how well VR technology can be used to simulate sensors and sensor configurations when designing Ubiquitous Computing (UBICOMP) systems; 2) to construct a VR design studio that facilitates exploration of alternative UBICOMP user interfaces.
- **Computing Science subgoal:** 1) To identify the best possible combination of computing algorithms and wearable sensors, for automatic ADL recognition; 2) to evaluate the interaction model "egocentric interaction".

Method

The prototype development and evaluation is performed based on a long-term four-step plan (Fig. 2) in which the activities in the VR phase (step two) are expected to be our current focus.

Understanding what is going on
The system's activity support is based on an interaction modeling framework currently under development called egocentric interaction, which among other conceptual components includes a situative model of identifiable objects in the space surrounding a specific human actor [2] (Fig. 3). Body-worn sensors are assumed to provide information on how everyday objects in the vicinity change state and location in relation to that specific human body. We believe that a wearable approach provides mobility, privacy, and personalization advantages which override the ergonomical drawbacks in the long-term.

Simulating sensors through VR
In order to speed up the design process, the actual identification of nearby objects as well as the sensing of body posture of the patient is initially simulated in a VR environment. The virtual environment used in the studies will initially be a home environment, developed using a framework for rapid development of Virtual Environments, Colosseum3D [3] developed at Umeå University. The framework contains an interaction method based on real-time physics which allows a user

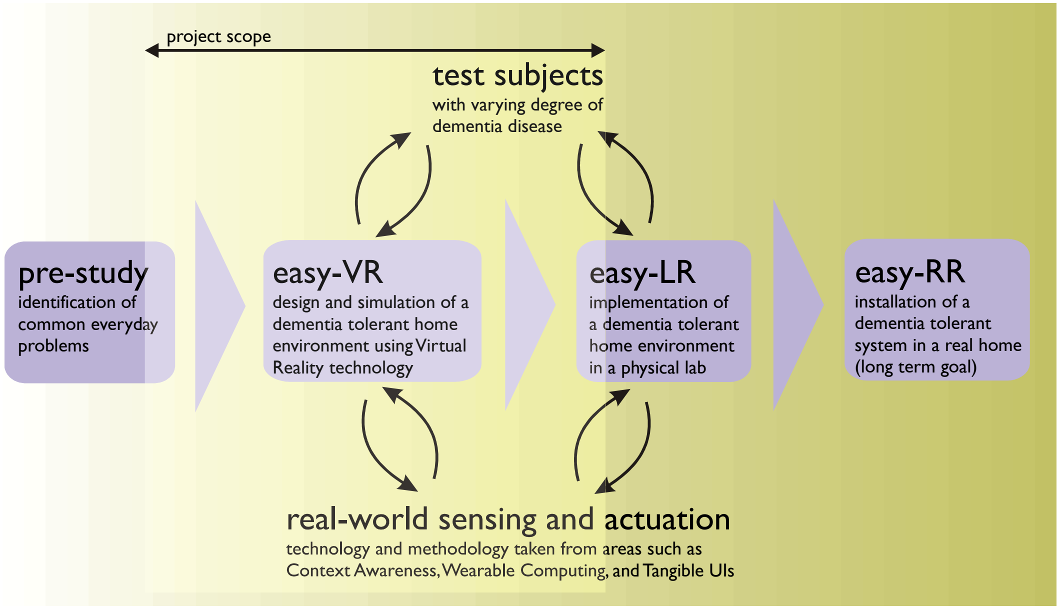

Figure 2. General system development plan for easyADL, and beyond.

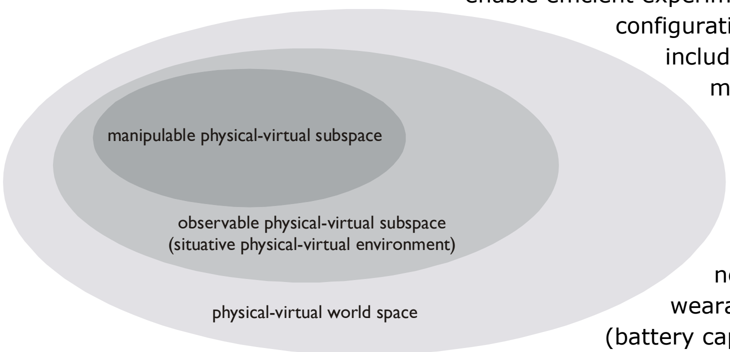

Figure 3. A situative physical-virtual space model [2].

in a natural way to interact with object such as coffee cups, milk parcels, cupboard doors etc. This setup will enable efficient experimentation with sensor configurations (candidate technologies include accelerometers, RFID, microphones, electronic compass) and activity recognition methods (candidates include Self-Organizing Maps, Growing neural gas, Hidden Markov Models), which may not be possible with existing wearable hardware limitations (battery capacity, processing power, etc).

What activities should and could be supported?
During the pre-study, three related ADL have been identified as being important and potentially feasible to support using available activity recognition algorithms and VR models: 1) to prepare coffee and cake; 2) to have a coffee break at the kitchen table; 3) to clean up afterwards including hand washing the dishes. These three activities correspond to activities described in the AMPS framework [4] as M-1; A-3; P-1; J-2. If support for these activities proves to be successful, the system will gradually be extended to support other ADL. Once a successful system design has been determined, a wearable prototype will be constructed and evaluated in a lab environment. Depending on the fidelity of the prototypes (both in the virtual and the real world), evaluation using real patients will be considered.

Although the shape of the wearable system's user interface is still an open issue, some possible functionalities and their connection to known dementia problems have been identified (Table 1).

Related work

Previous dementia support prototypes tend to be a) either focused on very specific activities, b) designed for activity monitoring rather than activity support, c) cannot handle major individual handicap differences, d) and/or not able to adapt to individual handicap changes over time (E.g. [5], [6], and [7]). The proposed idea of step-by-step assistance has to some extent been tried in [8] but only for very few predefined washroom activities. Shifting to a more adaptive modeling approach, the same research group is currently taking an approach similar to ours [9].

	Problems experienced by dementia patients	Examples	Potential approaches to address them
1	Memory	Forget people who are already known to the patient (or) forget important days like birthday, wedding day, etc.	1. Capture the events that need to be remembered and store it as historical data. 2. Provide a life album containing pictures, videos, audios, etc. from the patient´s history.
2	Sense of space	Unable to differentiate between "bathroom" and "bedroom"; "hospital" and "home"; etc.	1. Capture the manipulable space and observable space in terms of the objects present in it. 2. Provide visual/ audio/ tactile cues for the patient to find their way around in the home environment.
3	Sense of time	Unable to differentiate between "yesterday" and "tomorrow"; "Monday" and "Friday"; "day" and "night"; etc.	1. Keep track of occured events (historical time), current events (current time) and future events (future time). 2. Provide multimodal cues "rather than abstract numbers" to keep the patient informed about time.
4	Sense of quantity	Unable to differentiate between "empty" and "full"; "more" and "less"; "6" and "23"; "singular" and "plural"; etc.	1. Retrieve quantitative information of objects involved in the interaction by communicating with household devices. 2. Provide the quantitative information to the patient, if required.
5	Sense of quality	Unable to differentiate between "chair" and "table"; "cube" and "sphere"; etc.	1. Retrieve object category information of the objects involved in the interaction. 2. Help the patient interacting with unfamiliar objects, by associating it to familiar objects.
6	Behavioural patterns	Strange activity routines, not performing certain mandatory daily activities, etc.	1. Keep track of activity patterns. 2. Structure the set of activities to be performed in a day (routine) with considerable flexibility. 3. Provide a to-do-list to the patient.
7	Performing ADL	Unable to handle personal care (hygiene), to dress, to prepare food, to eat, to go shopping, to clean-up, etc.	1. Sense the current activity being performed. 2. Use clustering algorithms (e.g. Lifelong Growing Neural Gas, SOM, etc.) and statistical modeling (e.g. Active LeZi prediction algorithm, HMM, etc.) to perform activity recognition. 3. Provide step-by-step help in performing the activity.
8	Sense of cause	Unable to know that "if it rains one should wear rain coat" or "if you are traveling in a train, you should buy the ticket"; etc.	1. Use learning algorithms to teach the system about recurring cause-effect relationships. 2. Derive the environmental context and the user´s context, and identify any discrepancies 3. Help the patient to mitigate discrepancies.
9	Social interaction	Not able to understand the rules of social interaction.	No support (future research)
10	Mutual communication	Limitations in the understanding of language, gestures, symbols, etc.	No support (future research)

Table 1. Typical problems for dementia patients and some potential ways of adressing them through the use of a wearable support system. The easyADL project currently focuses on problem 6, 7, and 8 (which are to some degree depending on problem 2 and 3).

Acknowledgements

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Two questions we would like to be addressed in this workshop

1. When is it more beneficial to design technology for the caregivers rather than the cognitively impaired patients?
2. In what way does the design methodology (have to?) differ when designing for cognitively impaired as opposed to other user groups.

Author biographies

Anders Backman is a research engineer at the High Performance Center North (HPC2N), Umeå University. He has been working with project lead and software development in 3D simulations for more than seven years.

Gösta Bucht is presently coordinating the telemedicine development for the elderly for the County Council of Västerbotten and is a member of the steering committee for VR lab, responsible for VR in medicine. He has published approx. 100 original articles mainly concerning dementia, delirium, rehabilitation, telemedicine and abuse of the elderly and has given numerous talks on these subjects and on the usefulness of telemedicine and VR applications for the elderly. Gösta is co-leading the easyADL project.

Kenneth Bodin directs the VRlab at Umeå University, to which the easyADL project is affiliated. He holds a PhLic in theoretical and computational physics. His research interests include virtual reality simulators and enabling technologiesfor this area, in particular models and algorithms in computer graphics and physics based simulation.

Lars-Erik Janlert is professor of Computing and Cognitive Science at Dept. of Computing Science and leader of the Cognitive Computing research group. His research interests include interaction complexity, context awareness and knowledge organization.

Marcus Maxhall, BSSc, PhD Candidate, is a HCI researcher with focus on emotions induced via Virtual Environments. He is running the project EMOSIM, and has made studies within the Stroke Simulator Project.

Thomas Pederson, PhD, is a lecturer at Dept. of Computing Science and member of the Cognitive Computing research group. His research interests include Ubiquitous and Wearable Computing. Thomas is co-leading the easyADL project.

Daniel Sjölie is a research engineer at HPC2N/VRlab, Umeå University, with several years of experience of working with virtual reality, computer graphics and real time simulations, and a particular interest in simulation of human behavior and artificial life.

Björn Sondell, MD, PhD is a Specialist in Geriatric Medicine and a researcher with focus on patient related rehabilitation and cognitive functions among elderly persons. He is running the project USEFINE that deals with stroke related issues. Björn is a member of the Swedish Society for Medicine and the Swedish Medical association.

Dipak Surie, MSc, is a PhD candidate at the Dept. of Computing Science, Umeå University. His research interests include ubiquitous & wearable computing, human activity modeling, implicit & multi-modal interaction, cognitive science and psychology.