HERMES: Pervasive Computing and Cognitive Training for Ageing Well

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Abstract. HERMES aims at alleviating the elderly decline in both declarative and prospective memory, based on a set of ambient daily support and cognitive training applications. Its applications comprise memory aids and cognitive training games, both of which are presented in the paper. The paper introduces also the motivation of the HERMES project and applications. In addition it provides an overview of technical aspects in the areas of the project implementation in the areas of pervasive computing, as well as surface computing towards the utmost natural interactivity of seniors with computing devices.

1 Introduction

Sensors and pervasive computing [1] are gradually penetrating ambient assisted living (AAL) applications, with particular emphasis on applications for elderly users. We are witnessing a large number of "pervasive computing" for AAL, based on the wide range of approaches including tags, smart spaces and wearable computing [2-3]. Prominent examples of pervasive infrastructures for the provision of assistant services for seniors are apartment consoles, personalized databases, personal badge locators with help functions, RF and IR locators, environmental sensors for location, weight, and speech recognition, pervasive databases (personalized databases for status and history), a plethora of wearable systems, as well as infrastructures for user authentication, or secure networking.

However, the most prominent application for the aging population is the alleviation of cognitive problems, e.g., prevention of cognitive decline [4]. This is because these applications have an extreme societal impact stemming from the proliferation of ageing population with cognitive problems (e.g, by 2020, 40 million people will be affected by Alzheimer worldwide and by 2050, the number could be increased to 80 million). Applications targeting the cognitive decline aim at three complementary objectives: (a) boosting mental activation (e.g., via cognitive training), (b) enhancing social interaction and (c) promoting physical exercise.

At the technological forefront there are a number of technical/scientific challenges. The greatest one is to take into account the human factor and to bridge between the special requirements of the elderly and the technology to build. Technical challenges concern the integration of mental activation, social interaction and physical exercise, the design of ergonomic and easy to use interfaces. ICT for ALL cannot be isolated from human factors and therefore another technical challenge is to combine the human care and support factor with innovative ICT enabled services and independent living technologies. Also, at the organizational level, challenges concern the blending of ICT systems into existing processes - in homes, care centres, leisure centres, or hospitals. To this end, it is important to have the active involvement of gerontologists, caretakers, neuro-psychologists, or geriatric internists.

HERMES (http://www.fp7-hermes.eu) is an EU FP7 Specific Targeted Research Project which is in-line with above wave of AAL applications. HERMES takes a holistic approach to confront the above challenges. Overall, it provides cognitive care based on assistive technologies that combine the functional skills of the older person in order to reduce age-related decline of cognitive capabilities and assist the user where necessary. HERMES deploys intelligent audio, visual processing and reasoning technologies, and hinges on a combination of home-based and mobile devices in order to support the user's cognitive state. This paper presents the HERMES project, with emphasis on its system architecture, cognitive training games, as well as trial environment.

Following this introductory section, section 2 presents the problem of cognitive decline, which is the primary motivation for the HERMES project. Section 3, introduces HERMES as a pervasive computing: it highlights its technological skeleton comprising sensors, middleware and applications. Accordingly, Section 4 discusses the cognitive training component of the HERMES project, with reference to the design of the cognitive games, as well as to their surface computing implementation. Section 5 presents the HERMES trial environment, with a brief description of the number and characteristics users that will participate in the HERMES trials. Finally, section 6 draws the main conclusions.

2 Challenges of Cognitive Aging.

While crystallized intelligence (abilities, capacities and knowledge very practiced and familiar) remains or even gains in elderly people, fluid intelligence, that requires processing resources, declines with aging [6]. Age-related declines have been studied in episodic memory, working memory, prospective memory and memory for proper names [7] and also in more general aspects of cognition, such as executive function and attention [8]. Visual attention and visuo-motor coordination play a crucial role in the adaptation to technological devices which they are not familiarized with, such as could be computerized cognitive games.

Cognitive training for older adults has been a growing field in recent years, with increasing scientific knowledge about efficacy of cognitive stimulation programs [9]. It has been established that cognitive training improves cognitive abilities in healthy elderly people. It includes specific stimulation regarding concrete processes such as memory or language, as well as more general tasks based on broad constructs such as attention or speed of processing. This research about cognitive training is pointing to some extent to the achievement of the goals comprised by the concept of successful aging: a) the preservation of physical and cognitive functions; b) an active engagement with life; and also, to some extent, c) the absence of pathology, disability and risk factors [10].

In parallel to the increasing knowledge about cognitive training, a great amount of specialized software and commercial devices including the possibility of cognitive training has been placed into the market. Most of these programs are based on neuropsychological models of cognitive functioning and cognitive aging, but few of them have been scientifically tested through empirical studies with healthy older people.

3 Architecture of the HERMES Pervasive Computing System

The HERMES architecture is illustrated in **Fig. 1**, and consists of the following elements: (1) A number of sensors placed within the surrounding environment. In Fig. 1 we also envisage use of sensors that operate in outdoor environments (e.g., cameras and microphones embedded in a mobile device such as a PDA (Personal Digital Assistant); (2) A tier of perceptual components comprising visual analysis (e.g., face detection, face identification, person tracking), audio processing (e.g., speakerID, acoustic location, automatic speech recognition), as well as other sensor processing components. These components process the sensor streams, extract metadata and store them in the system's databases. Note that the perceptual processing engines deal mainly with meta-data derived from processing over the raw media data. This processing can occur either in an on-line real-time fashion, or based on later post-processing over the raw data; (3) A middleware library (Chilix) enabling perceptual components to provide metadata to the data repositories. CHiLiX bridges distributed and functionally diverse components based on XML-over-TCP communication.

CHiLiX acts as a flexible point-to-point message exchange library that accommodates multiple communication XML formats, while also supporting both synchronous and asynchronous message exchanges; (4) Data repositories storing application data and metadata. Application level data and metadata are held into two (logically) distinct repositories: A relational database enabling high-performance access to application data and a knowledge base repository providing knowledge conceptualization for application data that can be used for validating metadata, inferring new knowledge, as well as applying rules on the basis of a rule engine. The knowledge base comprises ontology models, which conceptualizes knowledge about the users' surrounding environment. A rule engine operating on top of the knowledge base executes application specific rules. Rule execution can be used both to validate information, as well as to boost context-aware behavior when a particular rule is met; (5) A data repository for storing raw sensor data. This is required for two main reasons: (a) There are several use cases where users like to access raw media data (e.g., to view a video segment or listen to an audio clip) and (b) In several case perceptual components extract metadata off-line i.e. after data are captured by the sensors and stored in the raw media database; (6) A data access layer implementing distributed data access services over the above data repositories. In the scope of our prototype implementation distributed data access is based on the W3C Web Services technology; (7) A Service Controller (SC) middleware which orchestrates the underlying data access, sensor processing and "playback" and rule execution components in accordance to application requirements. The service controller middleware is the "brain" of this architecture and allow allows the communication and information exchange of the components. It receives all applications' interaction and translates them to the appropriate data access and/or actuating services. Furthermore, it validates information and context against the knowledge base. In the scope of context-aware use cases, the SC component conveys identification of situations or fulfillment of rules from the rule engine to upstream applications. The SC may also interact with the perceptual processing engines in order to instigate post-processing of media data and/or "playback". The communication of the broker with higher level memory aid and cognitive support applications is also based on the Web services paradigm.

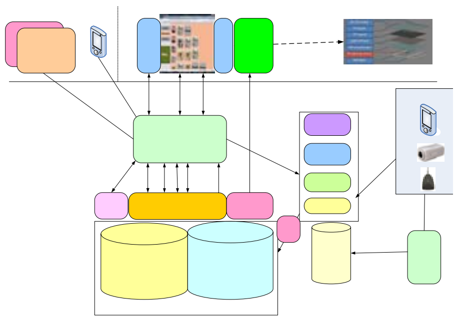

Fig. 1. HERMES system architecture

Based on this architecture, the HERMES consortium implements a wide range of memory aid and cognitive support applications. A characteristic example of such memory aid functionality is the video retrieval functionality (i.e. "*show me the video*") enabling aged users to retrieve and replay videos concerning the in-home visits from friends, family and caretakers. In terms of the architecture depicted in Fig. 1, the video retrieval memory aid functionality is implemented as follows: (1) Appropriately mounted cameras (i.e. sensors in the architecture) capture video, as visitors enter and leave an HERMES in-door environment; (2) Video processing components (i.e. A/V processing components in the architecture) such a person trackers detect the moment where a person enters the HERMES environment (smart space); (3) Metadata and tags (i.e. person id, "person entered" event, timestamps etc.) are stored in the HERMES Knowledge base (via the Chilix middleware). The Rule Engine undertakes to execute rules established over the metadata; (4) Rules instruct the Information Logging middleware to store the corresponding video stream for a specific duration following the "person entered" event. The video is stored in the Audio and Video database. Along with the video frames, meta-data such as timestamp, person identity (obtained via the person identification component) are also logged/stored in the Audio and Video database. The process is pervasive context-aware and real-time; (5) At any point in time, the user of the HERMES system can query the Audio and Video database about ("person entered") video-clips that relate to specific date/time and/or specific person. Since this information is stored in the database, it is retrieved and displayed to the user's terminal (e.g., PDA or multitouch screen).

4 Cognitive Training in HERMES

Cognitive Training Games

Cognitive games included in HERMES have been designed taking into account age-related changes in memory, executive processing, visual attention and visual-manual coordination, avoiding burden on these functions but stimulating them. One specific characteristic of the system is that, in contrast with other devices having a fixed database as a source of information, games developed in HERMES offer the possibility to use the information introduced into the system by HERMES users about contents of their own daily life. This distinctive aspect will allow us to stimulate memory for incoming events directly addressed to their daily situation, encouraging autonomy and sense of independence by supporting memory in an indirect, non explicit way.

The first two games to be developed have been HERMES Maze and HERMES Waterfalls. The aim of the HERMES Maze is to match appointment clues (e.g. Doctor visit) and time clues (e.g. 10:00 h.) from two different start points to an Appointment Sheet, which is inside the maze and serves as a reaching point. In a different mode of the game, a complete appointment card (containing time, content, place and accompanist) appears in one side of the screen and the user has to carry it to a Timetable avoiding a kind of monster from the epicentre of the Maze who increasingly approaches to the appointment. In the HERMES Waterfalls, the user has to pick up pictures falling down through two cascades and categorize them in one of the categories represented by cases. The game reinforces the behavior of catching the pictures while they are falling down, turning them harder to move when they get into a lake.

After the development of these games, more based on future appointments, a second generation of HERMES cognitive games will be developed taking into account elderly needs and perceptions about memory failures collected on user-requirements studies of HERMES target in three different European countries: Spain, Austria and Greece [11]. Observing complaints of elderly people about forgetting names and losing track about where things at home are, different tasks are being studied in order to stimulate lexical access or spatial working memory.

HERMES cognitive games and Surface Computing

HERMES cognitive training games are offered through novel ergonomic interfaces, which provide to aged users comfort, flexibility and natural interaction. In particular the HERMES end-user interface for cognitive training is implemented on multi-touch surface interfaces. Multi-touch screens and related interfaces are acknowledged to be motivating environments for executing cognitive training games (see for example [15]). Such interfaces fall within the wider wave of surface computing ([12], [13]), which is gradually more and more associated with ergonomic interfaces and natural human-computer interaction (e.g., [14]).

In the scope of the HERMES project, we have built a gaming environment over a multi-touch surface screen. This development has be based on libraries for finger tracking (developed in the Athens Information Technology (AIT)), as well as specialized middleware mapping low-level events from the tracker to high-level application events suitable for games authoring and development. In this way we have maximum control and flexibility over the cognitive games platform development, comparing to the option of using state-of-the-art general purpose proprietary multi-touch systems (e.g., Microsoft surface). Furthermore, this option allowed us to capitalize on AIT‘s leading edge finger tracking technology (Fig. 2).

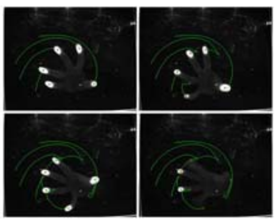

Fig. 2 Finger Tracking

Fig. 3: Multi-touch surface table

We designed a special multi-touch surface interface, which operates based on fingertips movements, which are very familiar to humans. This surface enhances interaction simplicity and makes memory support applications and cognitive training games more appealing to the elderly. A surface with multi-touch potential also allows developers to implement games with complex requirements. The surface is designed to be able to be embedded on a typical table (as shown in Fig. 3). This enhances the quality of the user's interaction with the device and the cognitive support applications. At the same time it is preferable over interfaces that require users to familiarize themselves with several devices (e.g. the combination of a keyboard, mouse and computer monitor), which usually results to confusion and features a demanding learning curve. The implemented interactive surface can integrate such a design on the same physical device. As part of future work we may investigate techniques for integrating the multi-touch system into standard furniture (similar to the Coffee Table from Savant A/V (http://www.savantav.com/). Furthermore, user centered design aspects of the games will be considered.

5 HERMES target population and trials

The user will be taken into account in phases of development and implementation, defining the game requirements with their help. The games will be tested in three different phases: (1) in the first phase, an expert group -composed mainly by neuropsychologists and gerontologists- will be invited in a focus group session in order to give their opinion about cognitive games: (2) in the second phase, the user-target group will be assessed by means of a focus group and an interview in terms to establish the usability and subjective value of the games, and to obtain feedback about the features of them that should be changed; (3) finally, the efficacy of these games will be tested. These testing tasks will be carried out in a lab environment and about 15-20 elderly people over 60-years and without cognitive impairment will participate on it.

6 Conclusions

This paper has provided a description of the EU HERMES project, with emphasis on both technological aspects, as well as the human factor. We strongly believe that HERMES sits at the leading edge in terms of technological developments, while at the same time having a great potential for contributing to the improvement of the cognitive function. The HERMES trials in Spain and Austria will involve aged users in realistic settings, and will help HERMES gerontologists and technologist in scrutinizing HERMES potential, while at the same time receiving invaluable feedback from improving the prototypes.

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