# *iTutorials* for the Aid of Cognitively Impaired Elderly Population

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**Abstract.** This paper introduces the *shared autonomy* concept on the context of Assistive Technologies (AT), in particular using an Intelligent Tutoring System (ITS) to support the performance of Activities of Daily Living (ADLs) while maintaining the intrinsic abilities of cognitively impaired users and relieving their respective caregivers from full time assistance. The key feature of this tutoring system is its capability to adjust the service to the user's medical profile and his/her environmental context. We present the obtained empiric results while designing and evaluating the service on diverse scenarios with real elder volunteers having a varied range of disability profiles.

**Keywords:** Assistive Technologies, Multi-agent Systems, Intelligent Tutoring System, Activities of Daily Living, e-Health.

## 1 Introduction

In the recent decades, the improvements in the Health Systems and in the Quality of Life (QoL) have systematically contributed to an increase of the life expectancy. Therefore, the number of elderly people has been raised, which implies more resources for aftercare and natural assistance in their preferred environments. This situation gets further complicated if elders suffer from memory disorders and/or other cognitive impairments [4].

The implementation of Intelligent Tutorials (*iTutorials*) is motivated by the necessity of providing alternatives to the constant care demanded in supporting elderly population with cognitive impairment through the performance of basic ADLs. The resulting tool follows a simple and intuitive model of task guidance where instructions are provided in sequence. The list of suitable tutorials for a user to perform is selected according to his/her medical profile. For instance, if the user present a certain weakness on the right side of the body as a result of a neurodegenerative disorder, the system will not offer those tutorials requiring

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a certain level of strength and coordination from the user. A solution involving such functionalities necessarily involves teams of Artificial Intelligence (AI) techniques, intelligent sensors and physicians' knowledge [7].

### 1.1 Plan of the Paper

Section 2 is intended to give readers a general idea of the *SHARE-it* project in order to contextualize the service. Section 3 addresses the key features that characterize this application, while section 4 is focused on describing *iTutorials* at a technical level. Section 5 presents the results obtained during the experimentation phase. Finally, we give some concluding remarks and draw foreseeable future lines of research.

## 2 SHARE-it

*SHARE-it* (Supported Human Autonomy for Recovery and Enhancement of cognitive and motor abilities using Information Technologies) was a EU FP6 funded project which addresses the issues of enhancing the QoL and independence of elderly people with cognitive and physical dysfunctions [10,1].

The final architecture of *SHARE-it* is composed by a conjunction of different elements such as sensor networks, robotic platforms or a Multi-Agent System (MAS) in charge of providing assistive services, being *iTutorials* one of them. Similar approach has been recently reported in [6].

### 2.1 SHARE-it MAS Structure

When having the ambition to endow artificial systems with competence in assisting humans within home locations, a large number of software components are needed. Each of these components, when having some autonomy and designed to percept from its environment through sensors and acting upon that environment through actuators are viewed as intelligent agents [9].

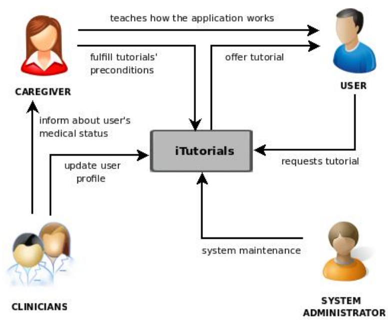
One of the software components of *SHARE-it* is the MAS [3], where agents interact and collaborate among themselves, obtaining input data from other elements within *SHARE-it*. The most relevant agents within the MAS regarding *iTutorials* are: the *Patient Agent*, which is responsible for all the functions related to ADLs such as selecting the suitable tutorial for assistance or tracking users through multistep activity performance; the *Environment Agent*, which percepts the current location of the user through the sensor network; and the *Home Agent*, which stores the user's medical profile in the server.

## 3 *iTutorials*: An Intelligent Tutoring System

*iTutorials* are conceived as an assistive system to help users presenting a mild or moderate cognitive decline through the realization of ADLs. Each of these activities that *iTutorials* supports is modeled as a set of simple sequential actions comprising a textual guideline, an audio track and a video footage showing *how* to accomplish the task. This service makes an approach to provide activity guidance according to two different key factors, further explained in the following subsections: (1) the user profile defined by clinicians, (2) the user's actual location within his/her intelligent habitat.

Regarding the use cycle of the application, a list of tutorials suitable for the user to perform are shown when clicking on the *iTutorials* button. Tutorials are grouped into different categories, such as cooking or self-care. First instruction is always intended to check if any of the items needed for the activity is missing. At the end of each directive, the user can decide to move forward to the next step or to quit and come back to the menu. Figure 1a shows the *preparing coffee* tutorial in execution.


**(a)** Screenshot of the Tutorial Execution




**(b)** Interaction Flow among Actors

**Fig. 1.** *iTutorials* Graphics

One of the main goals that this assistive service pursues is to reduce the potential dependence elders have in their caregivers on a daily basis. Therefore, the intervention of people with supporting roles has been reduced to very specific purposes. Figure 1b illustrates the directional interactions among these actors and the system.

In order to determine which ADLs might be supported by a procedural tutorial, two types of activities were considered: those necessary tasks for primal functioning consisting on self-care routines, and those activities to be performed on a regular basis by the users while being in their preferred environment. The number of steps composing each tutorial is closely related to the complexity of the corresponding ADL. For example, cooking activity can vary from a very simple set of atomic actions (*preparing sandwich* tutorial) to a sequence of instructions involving carrying heavy kitchenware (*cooking pasta* tutorial) or performing actions that demand a fine motor coordination (*preparing coffee* tutorial).

### 3.1 User Profiling

*iTutorials* are conceived to support the independence level each user presents, offering a customizable service with different degrees of assistance. A typical user of this system is defined as an elderly patient with cognitive and/or physical disabilities on a mild or moderate degree, co-morbid conditions (dementia, neglect, aphasia), and functional loss from multiple disabilities leading to impaired self-dependency. In order to focus on those affections our particular target population most commonly presents, a set of medical descriptors were selected by clinicians to model the user profile: *visual and auditory impairment, fine coordination, cognitive impairments as: dementia, aphasia and neglect.* These set of attributes were diverse and descriptive enough to facilitate the division of the target population into different groups of users sharing similarities [8].

Evaluation of the resulting user profile was generally conducted at a 3 level scale: 0 - *none*, 1 - *mild degree* and 2 - *moderate degree*. Users suffering from a *severe* degree of impairment were not considered due to their critical worsening in basic human functions. Spatial neglect and aphasia, which are two neurological symptoms quite frequent in our target population and that significantly affect their autonomy, were assessed separately.

### 3.2 Contextualization

The quality of life and independence of elders living in smart homes designed under the ambient intelligence paradigm can experience significant improvements due to the increased support received from the environment. Particularly, this vision of ambient intelligence regarding *iTutorials* applies to environmental sensor networks, defined as manageable and controllable systems that work completely in the background, unobtrusively and discreetly helping users on a daily basis [5]. Information retrieved from these sensors via the Environment Agent allows the system to know the indoors user's current location, taking advantage from the ubiquitous context.

Acknowledging user's position within the environment, *iTutorials* are able to determine which are the user's preferred ADLs to perform in the current location considering his/her profile, and automatically adjusting the selection of contextual tutorials accordingly. For instance, if the user moves from the living-room into the kitchen with his/her wheelchair or walker, the system percepts that the location has changed through the sensors network and decides which tutorials among those recommended according to the medical profile can be executed within the new context.

## 4 *iTutorials* Implementation

Following subsections are intended to detail, on the one hand, the architecture used for the data package exchange between *iTutorials* and the Graphical User Interface (GUI), and in the other hand, the technology used for the implementation of the *iTutorials* intelligent module underneath the presentation layer.

### 4.1 Mechanism of Communication

The presentation layer corresponding to the GUI communicates with *iTutorials* through DLA connections using data packages. DLA architecture is used within

*SHARE-it* as a mechanism of communication based on a central element that manages the access and storage of the shared data from other modules. When some of the *SHARE-it* elements wants to send some information to the GUI or vice versa, a DLA input/output connection is opened and a defined DLA package in byte format with the requested data is sent [2]. Next subsection details at which point these connections are opened within the agent layer.

### 4.2 Agent Technology

JADEX[1], an agent-oriented reasoning engine for writing rational agents with XML and the Java language, has been used for implementing the MAS following the BDI model as an agent architecture. This model consists of the concepts of belief, desire and intention as mental attitudes that generate human action. The corresponding execution model for software agents is based on the notion of beliefs, goals and plans, which prescribe its behavior. Therefore, an agent has a set of beliefs and motivations (its goals) to be achieved, that can be pursued by executing plans. There are two main functionalities of the *iTutorials* that the *Patient Agent* needs to manage:

**List of tutorials.** When the user profile changes, two actions are triggered by this event. On the one hand, those beliefs corresponding to the user profile (visual impairment, sound impairment, fine coordination, aphasia, dementia, neglect) are updated in the belief base. On the other hand, the agent reacts by creating and dispatching a new goal in order to select the suitable list of tutorials for the user according to his/her profile. To reach this goal, the `RuleEnginePlan` is executed in order to simulate human reasoning by running the rule engine for determining the suitable set of tutorials.

**Contextual tutorials.** The change of location is the event which triggers the update of the contextual tutorials. The current room where the user is located is used to decide which set of tutorials, from those recommended to the user according to his/her profile, can be offered by contextualization. It is important to remark that while a specific range of tutorials are served to users when they change location, all the other tutorials are also available.

### 4.3 Human Reasoning

The necessity of introducing an intelligent layer on the system arises when human reasoning must be simulated using medical knowledge in order to determine which tutorials a certain user is able to perform regarding his/her cognitive and physical status. Taking profit of the more closely resemble to human intelligence that inference rules present, the reasoning simulation within *iTutorials* was implemented using a rule-based expert system.

Each of the rules corresponds to one of the available tutorials and follows the same pattern: the current values of the user profile (*e.g.*, the user has aphasia

[1] http://jadex.informatik.uni-hamburg.de/

and a mild degree of visual impairment) are compared to those descriptors set to determine the selection of a tutorial according to medical criteria. If the *if clause* is evaluated positively, the fact corresponding to that tutorial in the working memory is modified. Once all the rules are evaluated, the agent layer (through the `RuleEnginePlan`) obtains from the working memory the selection of suitable tutorials for the user to perform.

## 5 Experimentation Results

The *SHARE-it* testing phase took place in *Casa Agevole*, a pre-existing facility adapted for people with mobility issues as part of the rehabilitation center hosted by Fondazione Santa Lucia in Rome (Italy). Experiments lasted approximately three months and were carried out with the aid of 21 Italian volunteers (3-4 volunteers per group) presenting a varied range of cognitive disabilities.

The plan of action for the experimentation phase included a pre-test where the technical and medical team assessed the technologies involved in the testing case -called scenario- in order to confirm, on the one hand, that each element of the *SHARE-it* architecture was compliant with the specification, and on the other hand, that the integration of all the involved elements such as *iTutorials* was also safe and consistent [3].

A set of scenarios describing typical human-system interactions were chosen as testing patterns to evaluate not only the role of the different technologies involved but also the functional and technical throughput of the service [1]. Scenario 2, called *Pietro goes to the church*, was significant in terms of both functional and technical outcomes, implementing the feedback given in previous experiments. Hence, we following present it to exemplify the testing methodology.

### 5.1 Scenario 2: Pietro Goes to the Church

**User Description:** Pietro is an 80 years old man who lives with an informal caregiver. He suffers from a mild mixed disability after stroke with a hemiparesis and impairment in the executive function.

**Narrative Scenario:** Two years ago, Pietro suffered from a *stroke*. He recovered well and at the moment he needs only a light support to walk. Sometimes he is not confident enough in the sequence of actions needed to reach a goal. Today is Sunday and his caregiver takes a day off. At 11 a.m. Pietro gets a reminder that it is time to get ready to go to the church. The corresponding tutorial on how to put on his shoes and overcoat is displayed on his wheelchair's touch screen.

**System Functional Evaluation:** On the one hand, the task required that users were not at the same location during the tutorial execution and had to kept their concentration when moving around. In all cases, mobility was not perceived as a hindrance when following the tutorial. On the other hand, users were told how the interface worked before starting to perform the activity, so that they could be able to respond properly.

Regarding the *iTutorials*' presentation, changes previously applied to improve usability proved to be adequate in order to get more dynamic and simple guidelines. These changes included removing the confirmation-phase between each step or splitting long instructions into two steps in order to simplify instructions' complexity.

**Technical Evaluation:** the *going out* tutorial operated robustly and run flawless as expected. The service was handled in less than 0.5s, an acceptable response. Audio samples were recorded and added to the videoclips to made the understanding process easier. Voice guidelines proved to be very effective in terms of focusing users on what the instructions ask them to do. This scenario presented a tutorial that had to be followed dynamically on different places of the house, compared to others that have all the steps performed in the same spot. This fact was not reflected negatively in the technical execution.

**Outcomes:** *iTutorials* stand out to be one of the most effective service within *SHARE-it* providing clear instructions on ADLs. Although there was an upgraded level of complexity regarding the user mobility in order to perform instructions, results obtained suggest that no extra mental workload was added for the users. Changes previously applied to the *iTutorials*' presentation proved to be positive, since reluctance experienced by users toward the application was significantly reduced. Scenario 2 was very profitable as it permitted to detect impending pitfalls, tackling them in an early phase when it was still feasible to shape the system according to functional and non-functional requirements.

## 6 Conclusions

Clearly, societal resources are not seen to be sufficient to assist all senior citizens, and while human care cannot and will not be replaced, AT are expected to play a key role in the improvement of the elders' quality of life. In particular, the use of the ITS presented on this paper is considered to contribute to the *enhancement in place* of older adults, which refers to the possibility for elderly people to remain living in their preferred environment for longer periods with a reasonably good level of welfare and comfort.

Prior research in the AT field has addressed compensation technologies, interactive activity guidance and adaptive planning. However, no system has combined these capabilities with the application of user profiling and ambient intelligence in order to deploy a cohesive system for supporting elderly people affected by cognitive impairments through daily basic tasks. In this sense, the presented *SHARE-it* approach is innovative.

Although AT interventions are still not commonplace in medical practice, their broad applicability clearly justifies their relevant role in cognitive rehabilitation. The success of *iTutorials* as a customizable service lays the foundations for the development of a more adaptive system, permitting to extend its functionalities for a more complex service personalization. It is hoped that future deployments show how *iTutorials* can be seamlessly embedded in elders' preferred environment, improving their QoL by helping them through their ADLs.

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