ROBADOM: An Assistive Robot for the Elderly with Mild Cognitive Impairment: System design and Users' Perspectives

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Abstract. The ROBADOM project aims at conceiving an assistive robot capable of expressing some basic emotions and language in order to support the elderly with Mild Cognitive Impairment (MCI), living alone at home. In order to ensure the appropriateness of the design of this kind of robot, technical solutions as well as social, psychological and ethical issues of robot use in the elder care are investigated. This paper presents the system design and some preliminary results from our multi-disciplinary studies.

Keywords: assistive robot, elder care, ethical issue, mild cognitive impairment

1. Introduction

In the last years, many projects have addressed the use of robots for supporting elderly people aging in place. Research in the technical community has begun to identify specific needs and values future robotic technologies might support for the aged population. Some of these include support in managing the home; maintaining personal and household supply; monitoring and providing ambulatory support; and providing communication and social interaction [1], [2], [3]. According to Broekens et al. [4], robot research in eldercare concerning assistive robots comprises both rehabilitation robots and social robots. The first ones emphasize physical assistive technology. The second ones concern systems that can be perceived as social entities with communication capacities. Furthermore, studies on assistive social robots in eldercare feature either pet-like companionship robot whose main function is to enhance health and psychological well-being or service type robots whose main function is to support daily activities related to independent living.

Recent research, such as Nursebot project [5], Robocare project [6], Care-o-bot [7], CompanionAble project [8], and MOBISERV project [9] has been increasingly focusing on service type assistive social robots to support the elderly to live independently at home. The rationale for the development of this kind of robots is that the aged population experience different degree of cognitive decline (ranging from aged-related cognitive decline, mild cognitive impairment to dementia) which might lead to difficulties in performing complex daily activities and in some case to a loss of autonomy. In this context, this kind of robots are conceived to assist the elderly with cognitive impairment in the following ways: by providing assurance that the elder is safe and is performing necessary daily activities, and, if not, alerting a caregiver; by helping the elder compensate for their impairment, assisting in the performance of daily activities; and by assessing the elder's cognitive status [10].

In the same line with the recent researches, the ROBADOM project is devoted to the design of a robot-based solution, a "robot butler", for assisting daily living of the elderly: reminder of appointments and of medicines intake, management of shopping lists and cognitive stimulation. The specificity of our project lies in developing a robot capable of providing verbal and non-verbal interactions and feedbacks and therefore coaching the elder users during cognitive stimulation exercises.

2. Project objectives

The ROBADOM project addresses the following issues:

1. Social context for designing social robots: 1) define the robot appearance acceptable by the elderly and 2) investigate the perceptions, attitudes and preferences of the elderly toward an assistive robot at home
2. Develop the robot's behaviors to provide natural interaction with the elderly: 1) first technological solutions for an expressive robot and 2) verbal and non-verbal communication between elderly people and the robot
3. Study the issue of robot acceptance in the elderly
4. Study the impact of robot on the elderly users (e.g., emotion and cognitive states, quality of life…)

3. System design

In order to design appropriate robot behaviors, interactions between the elderly and a psychologist are studied. The study will bring out specific signals, which will be characterized, in order to build a robust model. These signals will then be integrated in a complex architecture, MIIRE, which is specifically created to manage the interactions between the robot and a user.

3.1 Triadic Interaction: detecting verbal and non-verbal signals

The interaction between an older person, a psychologist and cognitive stimulation exercises is a triadic interaction situation, as shown in Figure 1. In this situation, the psychologist explains to the older person how to do the exercise, how to correct or erase an answer, or just encourages him. Backchannels of the psychologist were important for the elderly to build self-confidence and therefore to do these exercises correctly. An older person sits in front of the touch screen with the psychologist at his right. A video camera is placed in a corner, in order not to disturb the older person.

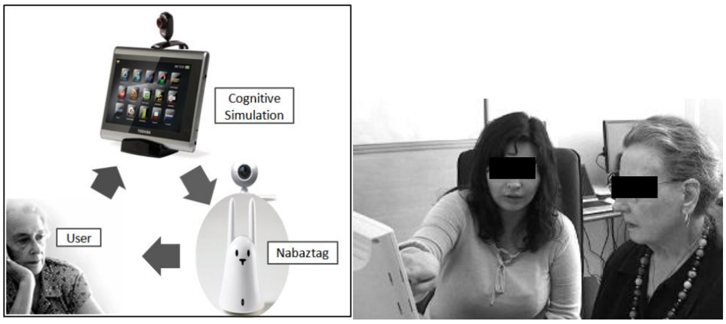

Figure 1. Triadic situation either with a robot or a psychologist

To establish interaction between the robot and the user, the robot needs to detect verbal and non-verbal signals, and send a feedback to the user. These social signals are fundamental for the regulation and the success of cognitive exercises.

To monitor the engagement/attention and to detect when the user requires encouragement and help, we propose a multi-modal system described in Figure 2, using:

- A Dialog system aiming to provide instructions and recognizing commands of the user during cognitive stimulation exercises.
- An Eye-contact detection aiming to detect where the user is looking at (the touch screen or the robot) as a signal of engagement/attention.
- Keywords spotting aiming to detect when the user needs feedback/helps/encouragement.
- Non-verbal behaviors triggered for providing multi-modal feedback/helps/encouragement.

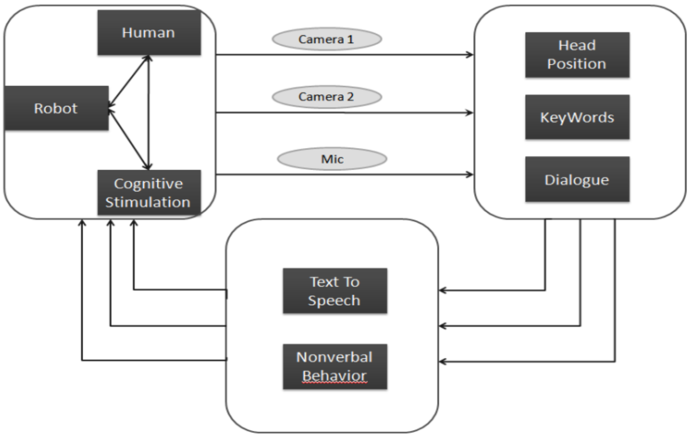

Figure 2. Multi-modal interactive system for on-line coaching

3.2 Engagement monitoring

To estimate where the user is looking at, and thus to monitor his attention and engagement, two cameras are placed on top of the touch screen and on top of the Nabaztag[1] to record user's movements. We want to detect if the user is talking/interacting or looking at the touch screen or Nabaztag. The algorithm consists of the following steps:

1. Detection of the face using the standard Viola-Jones detector [11] on each camera (touch screen and robot).
2. Double camera tracking with the Camshift algorithm with re-initializations.
3. Similar to face detection, eyes can be identified using a cascade of boosted tree classifiers with Haar-like features.

Eye-contact estimation is based on the combination of face and eye classifiers. The robustness of the eye-contact detector can be improved by thresholding the output of the eye-detector. The eye-contact detection system developed in this paper doesn't require calibration of the cameras but only the presence of the same user. Future works will be carried out on the extraction on more features such as movement analysis: head nod/shake detection as done in [12].

The eye-contact signal is used to monitor the attention/engagement of the user during cognitive exercises and further to adapt the robot's behaviors.

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[1] Nabaztag is used in this human-robot interaction experiment because its appearance might be well accepted by the elderly. Refer to section 5.1 for detailed results from our focus groups concerning the design of robot appearance.

3.3 KeyWords spotting

The key idea here is to infer the intention of an older user by detecting some predefined keywords. After analyses of recorded sessions, we defined 5 principal intentions: greeting, validating, clarification (e.g., cancel, type… These are clarifications the user needs in order to process through the exercise), user being lost, asking for instructions. The study of the user's behaviors gave number of specific words the robot has to pay attention to – the KeyWords that are in fact essential to recognize what the user is really saying. A recognized KeyWord uttered by the user will trigger verbal and non-verbal responses that can differ depending on context: type of exercises, level of user's engagement and actions.

4. MIIRE: Interaction and Individualization Modules in Emotional Robotic

A complete architecture will be created to manage human-robot interaction. MIIRE takes input data from the multi-modal system and precedes them to different behaviors that the robot can express as output data. Indeed, the robot will have the possibility to express different kind of behaviors when triggered by a single input, in order to avoid repetitions of similar movements, which might bore users and thus break the interaction. This architecture is a base for the cognitive modeling of human-robot relationships. The applications of human-robot interaction field are very important. Moreover, robot has to perceive its environment and to build dynamic model of it.

Human-robot interaction is an emerging area of interest in which development and research are very active in many fields. The field we are working on needs new theoretical models, on one hand for the robotics scientists to improve the robot utility, and on the other hand to evaluate the risks and benefits of this new "friend" for our modern society.

Table 1: Several architectures

Architecture name	Owner	Year	Context
SAIBA [13] [14]	Lot of authors	2005	Communication of ACA
GRETA [14]	Pelachaud et al	2002	Expressive ACA
BDI [15]	Wooldridge et al	1999	Intelligent agents Model
PAT [15]	Jaques	2002	E-learning
Baghera [16]	Pesty et al	2003	E-learning
HRI Framework [17]	Lee et al	2005	Human-Robot Interaction
MEPAA [18]	Soueina	2003	Personality Model
Robovie [19]	Kanda et al	2005	Expressive robot
iGrace [20]	Saint-Aimé et al	2010	Expressive robot

The table 1 shows several architectures currently used by the robotic community, with their application areas, as a state-of-the-art reference. This list is not exhaustive but is representative of the diversity of the suggested solutions. It seems that a single architecture, which manages several kinds of output (robot, avatar, others...) does not exist. Moreover, each architecture deals with a specific domain so it is possible to find a general model as none of the implementations is general. That is why we want to suggest a new architecture which will not have these constraints.

The MIIRE architecture is an organization to manage a human-robot interaction. The input of the system is composed of several sensors which allow the robot to possess the knowledge of the human state and of the situation. MIIRE merges all collected information and computes the answer that the robot will express (the output).

Fig. 3 shows the first release of the implementation of MIIRE in our context.

The input is composed of a set of modules which analyze signals from sensors and send relevant information to the Input Coordinator. These modules can be:

- an attention manager, which checks if the person is concentrated on the exercises,
- an agenda which manages the different appointments,
- a news module which indicates which important event happens recently,
- a motivation module which allows to help and to encourage the user,

The Input Coordinator is in charge of sorting sensor data to avoid noise or wrong data. The relevant data is sent to the Interaction Manager which is the conductor of the architecture. Some modules can be implemented as:

- Event Analyzer: this module supervises data concerning human, environment, context, news, machine, etc. Information concerning current situation is acquired and analyzed and if a new event happens, the Event Analyzer warns the Interaction Manager.

- Dialogue Manager: this module manages the dialogue with the user.
- Knowledge Manager: this module stores past actions, relevant information about the user, the situation, some news and so on.
- Scenario Manager: this module represents interaction scenarios (which action to do, when to do ...) and the interaction ritual. It knows how to initiate an interaction; it knows communication rules, such as the timing to speak, etc.
- Planner: it manages the Scenario Manager and suggests which action or behavior the robot will express. Then it transmits information to the Interaction Manager which decides what the robot has to do.
- Cognition Manager: it adds an affective value in the architecture. It is in charge of giving the emotional state of the robot according to the situation and the emotional state of the user.

The Interaction Manager decides the action to do according to each module. If the person has a trouble, it is obvious that the current interaction will be broken and that the robot will do something to help her/him (for example, calling for help). The Interaction Manager provides the behavior to be executed of the robot to the Output Coordinator, which sorts data, if needed, and provides the answer to the output.
Three types of answers are possible:

- Reflex answer: this is the answer to a situation which does not require any reflection or decision making.
- Coaching answer: it allows the robot to encourage and assist the user during the execution of a collaborative task, for example, in the case of cognitive stimulation exercises.
- Emotional answer: allows the robot to express emotions and to send verbal or non verbal messages to the user. Emotions play an important role in the interaction on three aspects: they initiate, maintain and reinforce the interaction.

Finally, MIIRE computes the final answer to express and provides as an output the behavior the robot has to adopt, directly referring to the answer. The output can be gestures, postures, facial expressions, speech, eye gaze, body language, sounds, music, light, impulsive movements, and even biological or physiological signs, such as breathing patterns.

The suggested architecture, MIIRE, is a modular architecture. It means that a set of modules, in fact computing programs, evolve autonomously and independently but with the knowledge of each other and with the capability of working together if necessary. The system works even if only few numbers of modules are activated. It allows an exprimenter to enable or to disable some modules according to expectations and needs of the older user. For example, if some users are disturbed by intensive light or fast movements, the MIIRE offers the possibility to completely disable modules or to set intensity of the light or the speed of movements, etc.

Finally, an asset of MIIRE is to infer more affective states, encompassing emotional reactions and non-verbal messages.

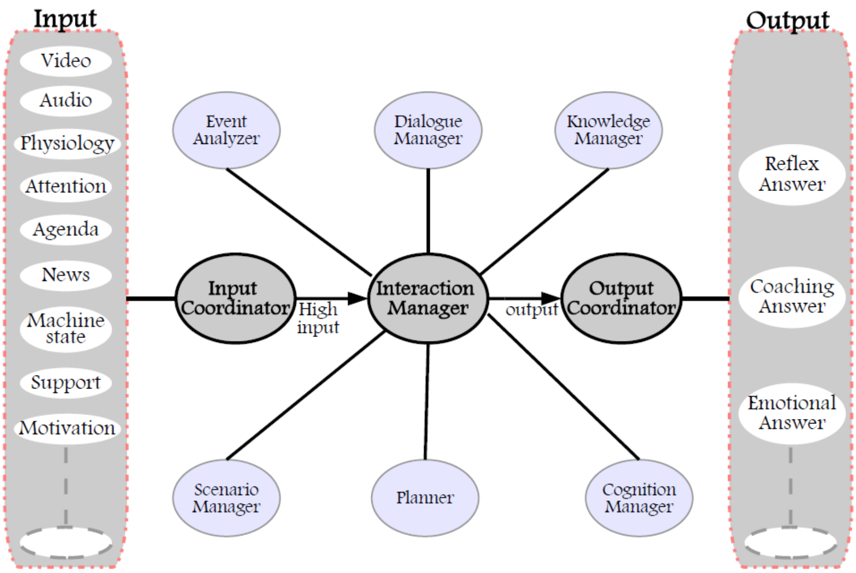

Figure 3. The first MIIRE project

5. Preliminary results

5.1 Define the robot appearance

Three focus groups were conducted in order to investigate how the elderly perceive a robot's appearance. A total of 15 older adults over the age of 65 (range from 66 to 89 years old) participated in this study. Seven participants suffered from mild cognitive impairment, according to definition criteria of Petersen et al. [21] while eight participants were healthy elderly without cognitive impairment. For more detailed descriptions, refer to Wu et al. [22].

The criteria of attractive robot appearance that we can get from our findings are as follows. First, robots appreciated by the elderly share some features: they are small (in comparison to human-size) and have some traits between human/animal and machine. According to Duffy [23], anthropomorphic or life-like features should be carefully designed with the aim to make the interaction with the robot more intuitive, pleasant, and easy. Second, the elderly seem to prefer a robot which looks like a familiar object in a home setting. This point corresponds to the design guidelines of robotic products proposed by Forlizzi et al. [3]. They suggest familiar product forms with augmented product functionalities will fit the system and maximize early product adoption. Further, elders seem to emphasize on the creativity in the design of robot appearance.

It is worth noting that many social and ethical issues were also raised during these focus group sessions. Participants expressed reluctance toward some humanoid robots which have inauthentic expressions and offer ersatz interactions and companionships. This invites us to open a dialog engineers in order to foster solutions which take into account the variety of social contexts in which the elderly lives. This invites us also to bring into question the way elderly users are implicitly considered and imagined by designers of assistive devices. Finally, we should consider elderly people not only as recipients of care, but also users whose needs have to be carefully identified, with their active participation.

5.2 Perceptions, attitudes and preferences of the elderly toward robots

In this study, we conducted semi-structured in-depth interviews with 15 community-dwelling older people with MCI. Their age ranges from 64 to 87 years old. They are 3 males and 12 females.

A guide consisted of three axis of questions was constructed and developped to provide a framework for interviews.

The first axis aimes to explore the problems and difficulties experienced in their daily life and the strategies uesd to compensate for them. Second, we asked the elderly to give their opinions on how technologies could enhance their well-being. Third, we explore the elderly's representations, attitudes and opinions towards robots and a number of robots' functionalities conceived to assist them. In addition, socio-demographic data and information on the use of technology were collected.

Our findings indicated that although the elderly with MCI experience discreet difficulties in their daily activities, they could compensate them with self developed strategies.

Most of the elderly interviewed use technological products (mobile phone, computer, GPS...) but they didn't consider that technologies could enhance their quality of life.

As for the representations of robots, most of the elderly perceived robots as automatic/autonomous machine, capable of assisting or replacing peoples for executing repetitive or dangerous tasks. Some mentioned robots as electronic appliances. Most of them didn't think robots useful for them for the moment. For those who found robots might be useful, they thought that they could be beneficial for fragile and handicapped people.

When we presented some functionalities of robots considered useful to assist them in their daily activities, most of the elderly were not enthusiastic about these functionalities. However, their appreciations toward some functionality, such as cognitive stimulation, reminder and object localization were rather positive. They were reluctant toward the idea of the "robot companion". They insisted on human contact and criticized that robots are inauthentic which could only offer ersatz companionship for those who are very fragile and lonely, for those who don't like human contact or for themselves in a future date.

5.3 Engagement detection of robot

A pilot experiment was conducted with some young adults to evaluate the relevance of the proposed interactive model described in section 3. The experimental setting requires a user in front of the touch screen and Nabaztag closely located as shown in Figure 4. The cognitive exercices can be started verbally by the user, after greeting the robot and asking for instructions. Then, the robot introduces the exercices by providing instructions. The user is only asked to follow instructions and to do the exercices. The proposed system is continously monitoring user's behaviors and provides feedbacks/helps/encouragements if necessary. Figure 3 reports the social signals exchanged in triadic interaction situation during cognitive stimulation exercises. As we can see, the user looks mostly at the touch screen, but this behavior is completely normal as the user is doing exercises on the screen. Consequently, most of the eye contacts are detected from the camera of the touch screen. Interestingly, when the user asks for information and/or helps from Nabaztag (KeyWord: How to), eye-contact detection with the Nabaztag is increased, which allows the system to efficiently trigger non-verbal behaviors and helps.

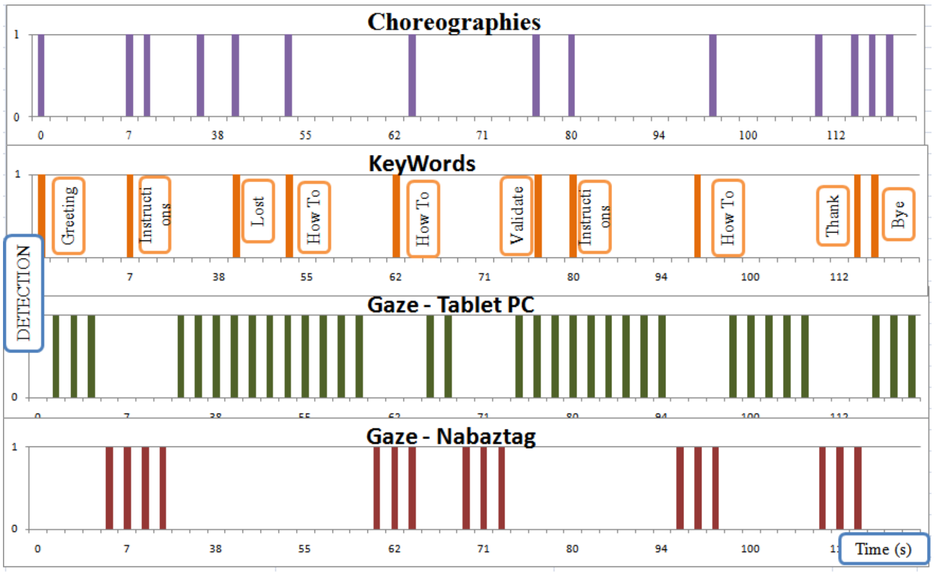

Figure 4. Interaction Loop while solving a cognitive stimulation exercise

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