RAMCIP: Towards a Robotic Assistant to Support Elderly with Mild Cognitive Impairments at home

Ioannis Kostavelis, Dimitrios Giakoumis,
Sotiris Malasiotis, and Dimitrios Tzovaras

Centre for Research & Technology Hellas, Information Technologies Institute,
6th Km Charilaou-Thermi Road, 57001, Thermi-Thessaloniki, Greece
{gkostave, dgiakoum, malasiot, tzovaras}@iti.gr

Summary. During the last decades the mild cognitive impairments (MCI) as well as the early stage of dementia comprises a societal challenge in the growing elderly population. This fact is highly related to the physical and cognitive decline of aged people, influencing the way they apprehend their environment and, thus, their daily activities. Towards this direction, the "Robotic Assistant for MCI patients at home" (RAMCIP) project, initiated by the European Union, intends to build a service robot that will operate in domestic environments with the aim to proactively and discreetly support older persons and MCI patients. The key component to achieve this goal is the design of a robot endowed with high-level cognitive functions, driven by advanced human and environment perception mechanisms, that will enable the artificial agent to autonomously decide when and how to assist. The paper in hand demonstrates the RAMCIP concept through identified user requirements and provides an overall system description. Additionally, the architecture design of the robotic system is exhibited here, firstly by providing a conceptual analysis and then by further decomposing the identified modules into functional components. The overall architecture envisaged in a user centric manner aiming to convert the real needs of the MCI patients into capabilities of the robotic assistant.

Key words: mild cognitive impairments, early dementia, robotic assistant, domestic environment, high-level cognitive functions, architecture design

1 Introduction

According to the Word Health Organization (WHO) [1] dementia is one of the major causes of disability and dependency among older people, whereas it is estimated that worldwide, 35.6 million people have dementia and there are 7.7 million new cases every year. Dementia is a syndrome of a chronic or progressive nature in which there is deterioration in cognitive function beyond what might be expected from normal ageing [2]. However, there is an early stage before

"The final publication is available at Springer via http://dx.doi.org/10.1007/978-3-319-32270-4_19"

dementia called mild cognitive impairments (MCI), which is characterized by abnormal memory performance for age but with normal general cognition and preserved normal activities of daily living [3].

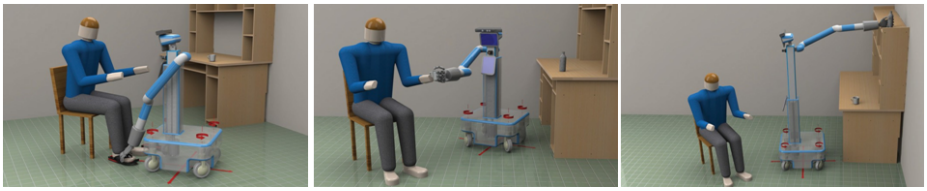

Fig. 1. The conceptual robotic platform with the manipulation hand as envisioned in the RAMCIP system.

Ageing is typically associated with physical and cognitive decline, altering the way an older person perceives and interacts with its environment. The thinks are getting worse at early stages of dementia, where elder people are not fully aware of their cognitive impairments and in this respect, their participation in everyday activities inherently involves significant risks. Furthermore, as soon as MCI patients recognize their tendency to forget necessary actions during daily activities, the likelihood of resigning from those activities increases. In turn, resignation from daily activities may also lead to negative emotions, reduced self-respect and potentially depression, increasing among others the probability for the person's health state aggravation and the potential for MCI to evolve into dementia. This stage is very crucial to be foreseen and anticipated prohibiting thus the impairment of the cognitive condition of the patients. In order to succeed this, the last decades persistent research endeavors in the area of service robots revealing methods that significantly assist elderly and support their independence. More precisely, the conducted research brought to the surface robots capable to autonomously move, to provide entertainment and telepresence functions, to learn and bring objects, to detect falls or even to assist the older person to move safely around the house by removing small objects and obstacles. In [4] an add-on Intelligent Wheelchair System (IWS) was developed to help older adults with cognitive impairments drive a powered wheelchair safely and effectively. On another aspect, the work described in [5] targeted the construction of a robotic wheel chair, where the entire system is part autonomous and part user-decision dependent (semi-autonomous). The ultimate goal of this work is the development of a Simultaneous Localization and Mapping (SLAM) algorithm allowing the environmental learning by a mobile robot, while its navigation is governed by electromyographic signals. Moreover, in [6], the authors presented a 2-degree of freedom robot suitable for rehabilitation of lower limbs. It utilizes neural network and genetic algorithm for the optimization of the control system. More findings in the area of assisting robotics for elder people are summarized in the objectives of past projects such as the HOBBIT [7] and the ACCOMPANY [8]. However, major challenges still need to be addressed towards service

robots of the future; ones that will be capable of assisting older persons in a wide variety of activities, discreetly and transparently, yet proactively and in tight cooperation with the human, acting at the same time as effective promoters of the patient's mental health, being solutions that will evolve along with the user, thus capable to match her/his needs as they evolve over time.

To this end, the RAMCIP project aims to research and develop a novel service robot, capable to proactively assist older persons in a wide range of daily activities, being at the same time an active promoter of the user's physical and metal health. The RAMCIP robot comprises three basic objectives which are summarized as follows:

- the development of cognitive functions based on user and home environment modelling and monitoring, allowing the robot to decide when and how to assist the user;
- the development of human robot communication interfaces, focused on empathic communication and augmented reality displays;
- the establishment of dextrous and safe robotic manipulation capabilities, which, to the best of our knowledge, applied for the first time in service robots introducing assistance activities that involve physical contact.

The rest of the paper is organized as follows: in Section 2 the overall concept of the RAMCIP system is described, while the basic user requirements and their mapping to the system design are outlined in Section 2.1 and 2.2, respectively. Moreover, an conceptual software architecture analysis is summarized in Section 3, while a brief discussion on the acceptability issues is exhibited in Section 4 In Section 5 conclusions about the presented work are drawn.

2 The RAMCIP Concept

The RAMCIP robot is designed to assist MCI patients in their day life activities by encoding the basic needs and requirements of such people. It retains a wide range of mechanisms to observe and perceive its environment, as well as a human oriented notion to track his/her activities, while it simultaneously assess the person's cognitive and physical skills. To succeed this, the robot shall act in a safe, proactive and discreet manner employing high-level cognition with the capacity to decide when and how intervene to provide assistance. The latter will be accomplished either by initiating Human Robot communication routine or by fulfilling a robotic manipulation task, yet through an autonomous decision making mechanism.

2.1 MCI-User Requirements

The robotic assistant described in this work will be able to assist in specific occasions in the day life activities, which stem from the MCI patients' requirements. Here we append a clustering of the most indicative requirements which

the RAMCIP robotic assistant is challenged to carry out during the cohabitation with an MCI patient.

1. **Taking medication:** The robotic assistant would be responsible to facilitate the his/her medication routine. This could be accomplished either by reminding the user that is time to receive the medication or by fetching it to him/her. Additionally, the system should be able to assess the correctness of the patient's medication intake.
2. **Eating activities:** The robot would be responsible to track the eating schedule of the patient and remind him/her for a missed meal.
3. **Dressing activities:** The robot would be responsible to help the person to select proper clothes and identify abnormalities during dressing, e.g. to properly button his/her cloths as well as to help him/her to take off the slippers.
4. **Food preparation:** The RAMCIP robot would be responsible to assist complementary the patient during the food preparation by fetching or lifting fallen objects, making thus the cooking task less laborious.
5. **Socialization:** The robot would help the person to be social active by reminding him/her to come in touch with family or friends or by reminding him/her about important dates.
6. **Lower-body treatment activities:** The robot would be responsible to carry out activities that could harm the patient's waist, while it simultaneously should be able to help the patient to put his/her feet on a footrest.
7. **Managing home and keep it safe:** The robot would be responsible to continuously monitoring and prevent dangerous situations at home e.g. switch off the oven button that the patient might have forgotten.
8. **Maintaining positive affect:** The robot will be responsible to observe the patient's affective state by analyzing a series of observations, while it simultaneously will apply strategies to help her/him mountain positive outlooks.
9. **Exercising cognitive and physical skills:** The robot will be responsible to continuously monitoring and prevent dangerous situations at home e.g. switch off the oven button that the patient might forgot.

2.2 Supporting MCI patients through the RAMCIP System

Towards the fulfillment of the above mentioned requirements the RAMCIP robot shall have advanced high-level cognitive functions as described in Fig. 2. These functions will be driven by thorough modelling and monitoring of the home environment and the user, allowing the robot to take optimal decisions regarding *when and how* to provide assistance, in a proactive and discreet way. Since assistance provision is deemed necessary, the robot will perform either **communication** to the user, or initiation of a **robotic manipulation task**.

Therefore, the RAMCIP platform will be specially designed in order to enclose all the aforementioned attributes. Except performance, the main concern is the safety of the user, since the RAMCIP robot will be designed for physical Human Robot Interaction applications (pHRI). Therefore, the entire robotic

platform will be designed by taking into account safety issues inherent in robotic applications for human inhabited environments. Specific parameters are taken into consideration involving the inertia of the moving parts to be kept as low as possible, the compliance of the robot links as well as the robot surface to be covered with soft materials, avoiding thus human injuries in case of physical contact. From the hardware architecture point of view several sensor inputs will be utilized to perceive the environment and the human presence. RGB-D sensors will comprise the main visual input for sensing, while emphasis will be given to the depth data concealing thus sensitive and private data of the user's dailies activities. Laser range finders will be utilized for the robot safe navigation and collision avoidance within the house. RAMCIP aims to go beyond the the current state of the art in safe robotic manipulation by developing a robotic manipulator of a workspace comparable to that of a human arm, overall weight of less than 10kg and payload of 5kg. The initial design of the robot foresees a hand mounted at the end of this arm with at least three fingers including a thumb with more than three degrees of freedom per finger ensuring dextrous grasping. Considering the communication part, human robot interaction will be established on multimodal, adaptive and empathic channels, realized through the fusion of touch-screen, voice, gestures and projective augmented reality-based interfaces. The robotic assistance tasks will be performed through either dextrous manipulation methods enabling safe object grasping, manipulation and handover, in inaccessible places including reaching of objects difficult for the user to reach (e.g. high placed objects), or through physical Human Robot Interaction during intentional and unintentional contact.

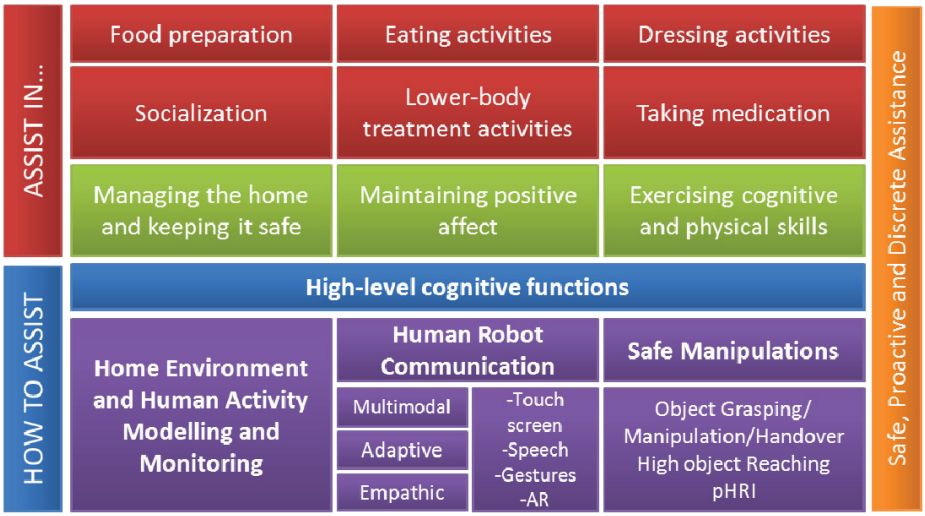

Fig. 2. The conceptual analysis of the MCI patients needs and RAMCIP vision toward future domestic service robots for such populations

3 Conceptual Architecture of the RAMCIP System

In order to exhibit the solutions provided by the RAMCIP system, to assist the MCI patients, a conceptual software architecture will be presented here. The software to be developed within the RAMCIP scope will retain both passive perception strategies of the user and the home environment as well as active engagement solutions with the robotic platform. The RAMCIP software architecture can be decomposed into "conceptual modules", clustered "functional components", available models from the user and the environment and external data that may stem from the robot, the user or the environment. Each conceptual module comprises several algorithmic core routines which are responsible for the implementation of the subordinate functional components.

3.1 User and Home Environment monitoring and modelling

The user activity and behavior monitoring module, and the home environment monitoring module are the cornerstone conceptual modules of the RAMCIP system, as they connect the robot with the user and its surrounding environment. The continuously tracking of the home environment and the dynamic update of the 3D environment model, will enable the RAMCIP robot to be aware of its location in the house, its relative location to house objects and appliances, whereas moreover, it will be capable to understand also the position and state of objects and appliances.

The human activity monitoring module will be first of all responsible to identify and also recognize humans inside the house. RAMCIP shall be aware in case of multiple co-located persons, of who is its primary user, as well as persons directly related to her/him (e.g. a relative or caregiver). Upon human recognition, RAMCIP will be capable to track her/his pose, actions and complex activities. With the ultimate goal to assist MCI patients, apart from the detection of emergency situations, e.g. a sudden fall, specific emphasis will be paid to detecting cases where the user has forgotten important steps of actions e.g. the user has forgotten to turn off the oven.

Moreover, the capability of RAMCIP to recognize its user and understand her/his behavior will be based on the system's user modelling engine. This will encode both (a) generic knowledge regarding how actions compose activities and how activities compose behaviors, as well as (b) specific respective knowledge regarding its primary user (and also regarding for e.g. relatives), all encoded in the RAMCIP VUMs (Virtual User Models), which will be a virtual reflection of the user inside the RAMCIP user modelling engine.

3.2 High-Level Cognitive Functions

Toward enabling proactive and optimal assistance provision in a variety of use cases a major objective of the RAMCIP system will be to provide the robot with competent cognitive functions and reasoning. These functions will be included

in the Assistance Decision Maker (ADM) module of the robot. The ADM will employ the VUM, the user and environment state to drive the robot's decisions over *when* and *how* to initiate an assistance intervention.

Consequently, the cognitive functions will ensure the development of an obedient and proactive servant undertaking difficult or forgotten tasks, to provide the robot with such a behavior that will also assist the user in exercising physical and cognitive skills, through its own behavior. This will be based on maintaining a balance between acting proactively, counteracting the user's forgetfulness by undertaking tasks that the user has forgot, and informing the user of a forgotten task, discreetly urging her/him to take a relevant action. Therefore, upon deciding that assistance provision is necessary, the robot will select through its cognitive actions to either communicate with the user or engage in a robotic manipulation task.

3.3 Human Robot Communication module

Human robot communication will be orchestrated through the Communication Decision Maker (CDM) component, utilizing the user's VUM part encoding communication skills and preferences, as well as the user and environment monitoring system modules. The CDM will thus drive personalized and adaptive multimodal Human Robot communication based on touch-screen, voice, augmented reality and gestural modalities. The robot will be capable to automatically switch between different interaction modalities or fuse them, ensuring the provision of optimal HRI on the basis of user skills, behavior and context.

Human Robot Interaction will also be augmented through advanced empathic communication channels. On one hand, the robot should be capable to recognize the user's affective state, based on analysis of the user pose and gestures, in combination with facial expression recognition. The robot will also employ an empathic display, realized as screen-based face, capable to show facial expressions enabling human compatible communication mechanisms.

3.4 Low-level Robot Control module

The low-level control module of RAMCIP will be responsible to handle RAMCIP's robotic manipulations, regarding either (a) interaction with the home environment, its objects and appliances or (b) physical Human Robot Interaction with the user. Autonomous locomotion of the platform will build upon mapping and navigation methods supported from the home environment monitoring and modelling module. The low-level control module will provide RAMCIP with novel robot manipulation capabilities including advanced grasping and dexterity functions. Through these advanced manipulation capabilities, the robot will be on the one hand capable of grasping a variety of objects in the home environment ranging from very small objects to dishes, cooking utensils, etc., and on the other hand, interacting with home objects or appliances, such as doors, light switches or the oven. Therefore, a task planner will be developed to coordinate

all the subordinate robotic tasks required to accomplish a specific robotic activities such as fetching objects that are placed at a height unreachable to the user. Moreover the robotic engagement in assistance activities that will involve physical contact between the robot and the user comprise an additional novel contribution of the RAMCIP system, e.g. the robot will be able to safely assist the user in lower-body treatment activities that require bending, such as changing socks or shoes, or assisting the user to place her/his feet on a footrest.

All the aforementioned conceptual modules as well as their subordinate functional components are summarized in the Fig. 3, where a flow diagram of the software architecture is illustrated.

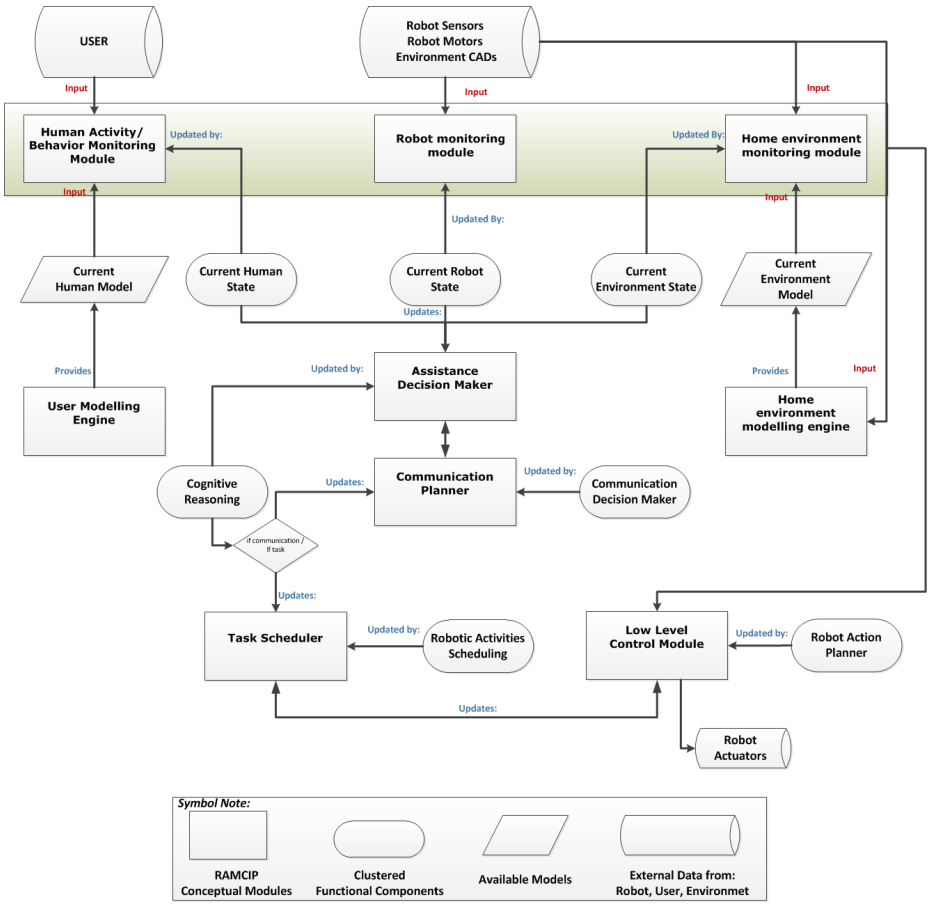

Fig. 3. The conceptual software architecture analysis of the RAMCIP system

4 Discussion

It is apparent that during the design and development of the RAMCIP system several parameters should be taken into consideration, the most important of which is the acceptability of the target users. Service robots intended for assisted living environments involve gender and ethical issues that should be paid clear attention. Gender-dependent differences are highly prone to appear in user needs and preferences, regarding either the assistance strategies or specificities in HRI, whereas privacy and ethical issues are inherently involved. Additionally, it should be stressed that the RAMCIP system would be developed so as to proactively and discreetly assist the user in his/her day-life activities by retaining autonomy and strong decision making mechanisms all developed in a human compatible manner. Thus, the intervention in user's everyday life will be distinctive and as smooth as possible, facilitating a concordant cohabitation. Moreover, it should be mentioned here that the ultimate goal of the RAMCIP system is not to replace the human caregivers services as this would be opposite to the willingness of the users, according to their witnesses in relative surveys. Albeit, it is expected that such a robotic system will act complementary to the work of human caregivers aiming to foresee and prevent hazardous situations in MCI patients's day-life.

5 Conclusions

In this paper the basic components of the RAMCIP system -a system targeting to support elderly MCI patients- have been presented. Emphasis has been given in the outline of some fundamental user requirements that appear in the early stage of dementia, while the RAMCIP capabilities to deal with these requirements have been assessed from the hardware point of view. Furthermore, the conceptual software architecture has been presented herein, highlighting the autonomy capabilities of the RAMCIP robot to be developed. The robotic assistant presented herein for MCI is has a specific role and is limited to specific tasks, since it is already too difficult for human being to help MCI patients, thinking of a robot doing this is a very challenging task. At this point it should be stressed that the objective of the RAMCIP robot is not to replace the presence of the care-giver but to render his/her task easier. The robot is expected to act complementary to the patients actions by contiuously monitoring his/her activities while it intervenes in a discreet manner either with communication or with by engaging in a robotic task. Likewise, some contemporary concerns about the service robots that operate in human inhabited environments have been underlined and solutions to these have been presented through the RAMCIP system. Summarizing, through the above, RAMCIP is anticipated to boost the benefits of service robotics, their robustness and applicability to realistic settings and eventually, their future adoption to operate in human environments.

Acknowledgments

This work has been supported by the EU Horizon 2020 funded project namely: "Robotic Assistant for MCI Patients at home (RAMCIP)" under the grant agreement with no: 643433.

References

1. WHO: Word health organization. Available at `http://www.who.int/mediacentre/factsheets/fs362/en/` (2007)
2. Spitzer, R.L., Md, K.K., Williams, J.B.: Diagnostic and statistical manual of mental disorders. In: American Psychiatric Association, Citeseer (1980)
3. Winblad, B., Palmer, K., Kivipelto, M., Jelic, V., Fratiglioni, L., Wahlund, L.O., Nordberg, A., Bäckman, L., Albert, M., Almkvist, O., et al.: Mild cognitive impairment–beyond controversies, towards a consensus: report of the international working group on mild cognitive impairment. Journal of internal medicine **256**(3) (2004) 240–246
4. How, T.V., Wang, R.H., Mihailidis, A.: Evaluation of an intelligent wheelchair system for older adults with cognitive impairments. J. Neuroeng. Rehabil **10** (2013)
5. Cheein, F.A.A., Lopez, N., Soria, C.M., di Sciascio, F.A., Pereira, F.L., Carelli, R.: Slam algorithm applied to robotics assistance for navigation in unknown environments. Journal of neuroengineering and rehabilitation **7**(1) (2010) 10
6. Aminiazar, W., Najafi, F., Nekoui, M.A.: Optimized intelligent control of a 2-degree of freedom robot for rehabilitation of lower limbs using neural network and genetic algorithm. Journal of neuroengineering and rehabilitation **10**(1) (2013) 96
7. Hobbit:: The mutual care robot. Available at `http://hobbit.acin.tuwien.ac.at` (2013)
8. Accompany:: Acceptable robotics companions for ageing years. Available at `http://accompanyproject.eu` (2014)