RAMCIP Robot: A Personal Robotic Assistant; Demonstration of a Complete Framework

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Abstract. At the last decades, personal domestic robots are considered as the future for tackling the societal challenge inherent in the growing elderly population. Ageing is typically associated with physical and cognitive decline, altering the way an older person moves around the house, manipulates objects and senses the home environment. This paper aims to demonstrate the RAMCIP robot, which is a Robotic Assistant for patients with Mild Cognitive Impairments (MCI), suitable to provide its services in domestic environments. The use cases that the robot addresses are described herein outlining the necessary requirements that set the basis for the software and hardware architectural components. A short description of the integrated cognitive, perception, manipulation and navigation capabilities of the robot is provided. Robot's autonomy is enabled through a specific decision making and task planning framework. The robot has been evaluated in ten real home environments of real MCI users exhibiting remarkable performance.

Keywords: Robotic Assistant · Integrated framework · Manipulation
Navigation · Perception · Task planning · Decision making · MCI

1 Introduction

The paper at hand aims to provide a comprehensive demonstration of a personal service robot, namely RAMCIP, which was researched and developed within the scope of the European Project "Robotic Assistant for MCI Patients at Home". This is a novel service robot able to proactively assist older persons at the early stages of dementia (MCI), in a wide range of their daily activities (see Fig. 1).

The classification of a robot as service, personal service or professional service robot, strongly depends on the task that the respective agent is dedicated to

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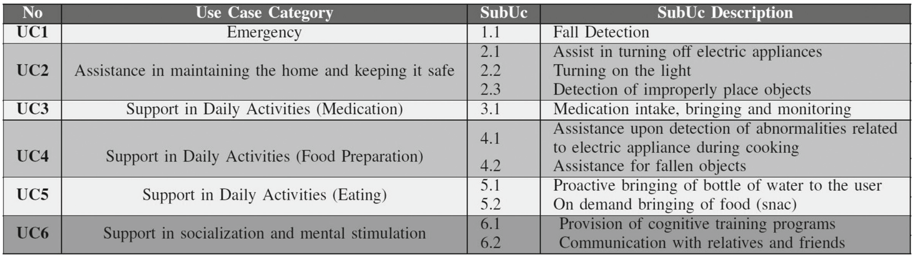
perform [24]. In this scope, contemporary robots require task-specific capabilities to cope with their mission (e.g. robot serving people in a house), however, there are also common abilities, which are vital for the majority of robotic applications and are always considered during the design of a new service robot. These abilities are highly related to the way the robots understand, interpret and represent their environment and the way the robots apprehend the human occurrence and activities within it [9]. Considering personal service robots the majority of them target domestic applications and can be classified as mobile servant, people carrier, physical assistant, personal care and health care assistant robots [7,19].

Fig. 1. The RAMCIP robot engaged on a medication assistive task.

There are several types of health care robots, an indicative classification of which can distinguish them among those that provide physical assistance, those that provide companionship, and those that monitor health and safety. However, they all share the same primary objective which is to improve or protect the health and lifestyle of the human user [4]. The demand for health care robots is more intensive for the aged population, where "aging in place" is present, in accordance to which older are living independently in their own homes and want to stay there as long as possible [21]. Contemporary paradigm of such robot can be the Kompaii 2 robot which aims to assist seniors and dependent persons at home. However, the situation is even more challenging for elderly being at early stages of dementia, in accordance to which they are not fully aware of their cognitive impairments and in this respect, their participation in everyday activities inherently involves significant risks. Towards this direction, the last years important research has been conducted for the development of artificial agents that will significantly assist elderly and support their independence. These efforts realized robots with significant capabilities related to autonomous motion and manipulations, entertainment provision, telepresence functions, objects fetching, detection of falls, mobility assistance to older persons, all necessary skills for addressing challenging tasks during human-robot cohabitation. Representative examples of such robots are referred herein. Notable assisting robots for the elderly have been derived from several research projects in the past. Specifically the HOBBIT project [8] combined research from robotics, gerontology, and human'robot interaction to develop a care robot which is capable to prevent falls, detect emergencies, bringing of objects and offering reminder to the users. The Hobbit robot was equipped with a mobile robot platform and 5 DoF manipulator accompanied with a gripper and was evaluated with real users in domestic environments. The ACCOMPANY project was build upon the Care-O-Bot®3 integrated in smart-home environment aiming empathic and social human-robot interaction, robot learning and memory visualisation as well as persons' monitoring at home [3].

A series of research projects are currently working towards the development of service robots, which could be used to support older adults at home. The RADIO robot objectives are focused on using the integrated smart home/assistant robot system as the sensing equipment for health monitoring with sensors that do not need to be discreet and distant or masked and cumbersome to install. Instead, sensors are realized as a natural component of the smart home/assistant robot functionalities, attempting to increase the levels of acceptance and unobtrusiveness. In addition ENRICHME robot [1] aims to enrich the day-to-day experiences of elderly people at home by means of technologies that enable health monitoring, complementary care and social support. ENRICHME's objective is to improve the quality of life of elderly people suffering of MCI, using a service robot within an assisted living environment. Opposed to RAMCIP, both RADIO and ENRICHME robots do not have a dexterous robotic hand and arm and act mainly as observers.



No	Use Case Category	SubUc	SubUc Description
UC1	Emergency	1.1	Fall Detection
UC2	Assistance in maintaining the home and keeping it safe	2.1 2.2 2.3	Assist in turning off electric appliances Turning on the light Detection of improperly place objects
UC3	Support in Daily Activities (Medication)	3.1	Medication intake, bringing and monitoring
UC4	Support in Daily Activities (Food Preparation)	4.1 4.2	Assistance upon detection of abnormalities related to electric appliance during cooking Assistance for fallen objects
UC5	Support in Daily Activities (Eating)	5.1 5.2	Proactive bringing of bottle of water to the user On demand bringing of food (snac)
UC6	Support in socialization and mental stimulation	6.1 6.2	Provision of cognitive training programs Communication with relatives and friends

Fig. 2. A summary of the target use cases for the RAMCIP robot.

Albeit the fact that significant steps forward have been achieved in the respective domain, major challenges still need to be addressed towards service robots of the future. Of such can be assumed the capability 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 patients mental health. The challenges that have been addressed in order to allow RACMIP robot to successfully realize its mission are summarized as follows:

- Development of a perception system suitable for continuous monitoring of the user and the environment.
- Establishment of multimodal human-robot communication interfaces.
- Endorsement of robust robotic skills, related to safe manipulation, grasping and navigation that enable safe robot interaction with the human and the environment.
- Provision of cognitive skills to the robot, suitable to enable it to optimally decide for its assistive interventions, while at the same time ensuring sequential skill applications for each scenario denouement, through a task planner that allows fail safe mechanisms.

Towards addressing the above challenges, a series of S/W and H/W modules were developed in the course of the RAMCIP project, carefully designed on the basis of detailed end user requirements and target use cases. The paper at hand aims to describe the overall framework of these components integration, starting from the target use cases and moving along to outlines of their key capabilities and how these were integrated, so as to lead into the RAMCIP robot, a robot that is currently being evaluated in a series of different real home environments (ten so far), of real end users, i.e. older persons with MCI. In this context, the paper underlines the importance of how robot cognition and task planning have been fused so as to orchestrate the subordinate S/W modules of the integrated robot and eventually, provides insight on the level to which this has led to effective robot operation on the target use cases, within the real domestic environments of the RAMCIP project pilot trials.

2 The RAMCIP Use Cases

In order to realize a robotic assistant useful for the target population group, i.e. MCI patients in our case, the user needs and requirements have been firstly identified. To achieve this a specific methodology has been followed [12]. In accordance to it, firstly, research questions were established towards analysing user needs and expectations. Then, a mapping among the posed research questions and the existing investigation approaches has been performed. In that stage, a literature survey along with moderated group discussions was established and surveys with questionnaires were performed. The outcome of this procedure was the user requirements elicitation and their prioritization considering the material obtained from the conducted surveys. The next step comprised the definition of the RAMCIP robot use cases, i.e. user-centred scenarios, which demonstrated interactions between the robotic system, the user and the environment. The main aim for each use case is to accomplish the task and achieve a planned goal. Due to the multitask nature of the RAMCIP robot, all potential activities stemming from the prioritized user requirements analysis, were classified into high level use cases (UC) and each one consisted of sub-use cases (SubUc), which are specific goal-orientated interactions between the robot, the user and the environment. The identified RAMCIP UC and SubUc are summarized in Fig. 2. Each SubUc is analysed as follows:

SubUc-1.1: The robot is capable of detecting a fallen user, approach him/her and establish communication about the user's current status. If needed the robot is capable of establishing communication with an external person/caregiver.

SubUc-2.1: The robot detects the state of a cooker appliance after a cooking session of the user. If a knob has been forgotten turned on, the robot firstly stimulates the user with communication to turn it off and, then, if needed it turns off the knob by engaging with a robotic manipulation.

SubUc-2.2: The robot can detect the user while walking around under low-illumination conditions and if necessary turns on a light switch with robotic manipulation.

SubUc-2.3: The robot can detect improperly placed objects after the user has interacted with them. Specifically, after the medication intake activity, the robot prompts the user to take the pill box back to its storage position. If the user does not perform the task, the robot is engaged in the scenario to fulfill the task with robotic manipulations.

SubUc-3.1: The robot is able to provide the user with reminders considering the daily medication schedule. The robot can also bring the medication to the user and monitor the medication intake activity.

SubUc-4.1: The robot detects the state of a fridge appliance after the finishing of a cooking session. If the fridge-door has been forgotten open, the robot firstly stimulates the user with communication and, then, if needed, closes the fridge-door by engaging with a robotic manipulation.

SubUc-4.2: The robot monitors the user and the environment during the cooking activity and upon detection of a fallen object, the robot notifies the user about the situation. If the object is graspable, the robot is engaged into a manipulation task to pick it up from the floor.

SubUc-5.1: The robot monitors the user during the eating activity. In case the user doesn't drink any water, the robot proactively brings a bottle of water to the user.

SubUc-5.2: The user communicates with the robot and asks for a snack or a bottle of water. The robot is capable of executing the fetching task.

SubUc-6.1: The robot prompts the user to participate in a cognitive training game which is integrated into the robot's communication interfaces.

SubUc-6.2: The robot monitors the user's emotions and in case of negative affective state detection, it prompts the user to engage in a telco-call with a relative.

3 The Robot Hardware Components

After the identification of the RAMCIP requirements, the target use cases and the available technology base, the robot hardware architecture was established. During planning the component list, a series of factors were considered in order to justify the necessity of each component and map its functionality to a user requirement, ensuring this way that the designed robot can be fully justified and can meet the posed specifications. The robot has been developed in an iterative fashion distinguished in two phases. Firstly, the V1 robot has been developed based on the preliminary posed requirements and use cases. The developed robot has been evaluated with real users and the feedback obtained was utilized for the construction of the V2 robot. Figure 3 exhibits the two versions of the robot. The basic hardware components are summarized as follows:

Mobile Platform: The mobile platform provides the locomotion functionality and is based on the 2DoF differential kinematics model. It hosts the entire computational system of the robot, offering lower center of gravity and at the same time ensuring lightweight construction of the rest of the robot body.

Elevation Mechanism: The elevation mechanism allows the robot to reach both higher (around 1,75 m) and lower (floor) locations with the same robotic arm.

Body: In the front of the RAMCIP body, interaction components are included such as microphone, tablet PC and speakers, allowing communication with the user.

Arm manipulator: The RAMCIP robot arm manipulator is relied in a 5 DoF kinematic model including also the prismatic joint of the elevation mechanism.

Hand and Wrist: The robot is equipped with a 2DoF wrist that maximizes the robot's workspace and holds a dexterous manipulation hand. The latter is a three-fingered robotic hand with nine degrees-of-freedom, suitable to perform grasping of different objects with various grasping strategies.

Head and AR-Module: The robot has a 2DoF head equipped with a display for facial expressions that enables robot-user interaction and augments it with affective cues. It also has a projector to interact with the user through augmented reality, since part of the multimodal communication is the ability of the robot to display pointers and information on a chosen surface/object. Both components are merged into a commonly motorized part.

Fig. 3. The RAMCIP robot; on the left the first and on the right the second version of the robot, after the iterative development procedure.

Perception System: The robot perception system consists of one RGB-D sensor mounted on the robot's head and two laser scanners mounted on the platform. The RGB-D sensor is utilized for the mapping, the environment monitoring and the human tracking. The laser scanners are utilized mainly for the robot localization and navigation and for leg human tracking.

4 The Software Components of the Robot

4.1 Perception Modules

Environment Hierarchical Semantic Mapping. The metric mapping solution adopted, is the RGBD-SLAM presented in [6], yet enhanced in terms of memory and speed management in order to be operable for large scale mapping requirements of real houses. The 3D metric map is constructed once during the installation of the robot to a new house. In that phase the robot is teleoperated and acquires color and depth images in order to progressively build the map, utilizing feature tracking and graph optimization techniques. The 3D map is utilized for the extraction of the dominant supporting surfaces (e.g. table, kitchen bench) of the house and the definition of the robot's parking positions for human and environment monitoring (e.g. robot parking position for the cooking monitoring) according the use cases. The semantic information is stored in an XML schema and comprises the following structure: the house environment is organised in rooms, the room types consist of large objects and frequently visited standing positions, the large objects are related with the robot parking positions and with small objects. The small objects are organized in terms of their attributes, their grasping strategy and their relations to other objects [13]. Then the 3D map is top down projected and converted into a 2D costmap to be utilized for robot navigation (see Fig. 4).

Large and Small Object Detection and State Tracking. Tha RAMCIP robot is capable of detecting and tracking the state of small and large objects, a functionality that allows it to successfully monitor the human activities and grasp objects from various places. Considering the small object detection and tracking, a dedicated custom tailored solution has been developed based on RGB-D data. Specifically, a model based 6Dof object detection algorithm has been developed as described in [5], which has been utilized for object grasping purposes. A lighter version of this algorithm has been also utilized for performing initial detection of small objects on a supporting surface and then a connected component based solution has been applied for the tracking of such objects while manipulated from the user. The approach is applied when the robot is at a human activity monitoring state and the human actions and manipulated objects should be tracked.

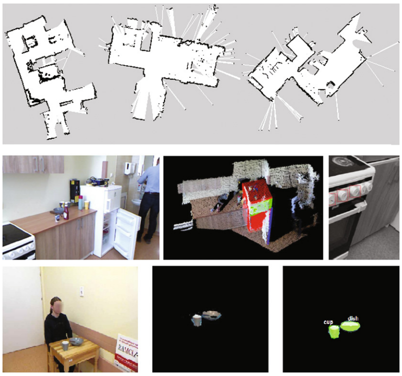


Fig. 4. The first row illustrates examples of metric maps in different houses, the second and third rows exhibit examples from the large object state tracking and the small object detection and tracking components respectively.

The large object (fridge, cooker) state tracking component is essential for the detection of the state of the electric appliances in the house environment. Due to the great unevenness of the appliances that can be met in different houses, a holistic solution has been developed. The latter comprises the a priori rough modelling of the home appliances during the robot's installation in the environment and the anchoring of their pose to the hierarchical semantic map. Given that the robot is parked in a specific pose, a search is performed in the hierarchical semantic map, to acquire a list of the large scale objects that are in the current field of view. The retrieved object IDs are used to recall the corresponding 3D models from the respective collection of models in the hierarchical semantic model. The retrieved object models undergo multiple registration (ICP) steps in order to be aligned with the point cloud in the observed scene. Then, depending on the context of the robotic task, a large object state tracking based on articulated ICP is performed to detect the state of the parts of the observed object (e.g. fridge door), or vision based processing techniques are applied to detect the state of the respective appliance (e.g knob state detection). Illustrative examples of these approaches are exhibited in Fig. 4.

Human Monitoring. The human monitoring module involves first of all the continuous detection and tracking of the human in the environment and the inference upon the performed daily activities. A hybrid methodology for the human detection has been developed, comprising of RGB-D skeleton and leg tracking components. The first one relies on a model based 3D skeleton joint tracking algorithm presented in [22] and is appropriate for full and partial human observability in the scene. The second one, is a laser based human tracking relied on the methodology introduced in [17] and is capable of human tracking while the robot is moving or the user is outside the camera's field of view. The seamless integration of the two approaches ensures continuous robot awareness regarding the human presence and location in the house.

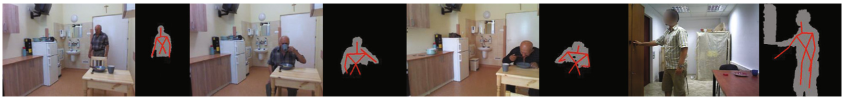


Fig. 5. Characteristic examples of human tracking used for action recognition in occluded scenes.

The human action recognition module is the one developed in [20], which is specifically designed to operate in realistic conditions, with robotic platforms. It employs the tracked human's skeleton joints and by extending the classic EigenJoints [23] method, it improves recognition robustness for a series of actions involved in common daily activities. In addition, it associates specific actions with information related to the user's manipulated objects, taking into account that several actions may be similar, yet performed with different objects e.g. "eating" can be analysed as a "hand to mouth" atomic action with object "spoon" and drinking can be analysed also as a "hand to mouth" action with object "cup". Figure 5 illustrates some characteristic examples of human tracking used for action recognition in cluttered environment. Last but not least, the human monitoring includes also a user affect recognition module. This is based on multimodal data, derived from facial expressions recognition and biosignals monitoring. Emphasis is put on the detection of the user's negative emotions, such as sadness or stress. During the robot's installation at a user's house, baseline recordings are taken from the specific user, to help the respective machine learning system counteract common issues of affect-related between-subjects variability.

4.2 Action Modules

Navigation. The RAMCIP navigation framework has been designed based on the existing architecture of ROS, known as the navigation stack. This is a framework that orchestrates the robot odometry information, the sensor's stream, the constructed maps of the environment and the velocity commands send to the platform. The reason for the selection of the navigation stack is that it already implements a communication architecture among the modalities that need to work together in order for the robot to navigate successfully. The overall navigation approach is structured in a global (GPP) and local path planning (LPP) framework. For the GPP of navigation, a socially-aware path planning method was developed which explicitly takes the human into account in terms of human motion prediction, extensively described in [15]. The predicted path is extended by a human comfort zone which is derived from proxemics theory on human-human interaction. By including the result in the cost-map structure for global path planning, trajectories that avoid unnecessary proximity to the human are derived. This enhances the acceptance of the robot by the human and helps to avoid hazardous situations already in the early stage of off-line planning. For the execution of planned trajectories a dynamic window approach has been integrated as a local planner [16]. It allows the system to find locally optimal solutions in velocity space that are collision free and explicitly consider the dynamic capabilities of the robotic platform, thus guaranteeing safe solutions. The approach works on a local map obtained from online laser range scanners and RGB-D sensors. In many cases, the robot can find its way around a priori undetected obstacles without having to re-plan, bringing increased robustness to the navigation system.

Manipulation. The manipulation system of RAMCIP robot is endorsed with safety features. An adaptive compliance controller has been implemented [11] as a nominal controller that adapts arm stiffness and damping parameters dynamically to the task, the risk of collision and uncertainties stemming from the perception system of the robot. The adaptive compliance allows the robot to efficiently reduce the collision impact in the event of unintended contacts while being stiffer and executing motion accurately when the environment is collision-free with a higher level of confidence. For the arm motion, biologically inspired motion profiles are used, aiming at a more predictable behaviour. To avoid unintended collisions whenever possible, an invariance control scheme is implemented that supervises the nominal control with respect to safety boundaries that are defined as hard constraints to the system. This model-based method takes the dynamics of the robot explicitly into account which allows for a mathematically proven adherence to boundaries. An augmented version of this approach was developed in course of this task to enable the adherence to smoothness requirements for system states and control inputs.

Grasping. The RAMCIP robot targeted interaction with various objects that retain different geometrical attributes. For example in the medication intake activity, the robot has to grasp very small and flat objects (pillbox), which may be at ashelf of increased height, while for the assistance on eating and drinking the robot should be able to grasp a bottle of water. It is apparent that for each object and context in terms of supporting surface and surrounding environment, a specific grasping strategy should be developed. Thus the grasping affordances are associated with the small object and stored in the hieratical semantic map. To this end, and in order to compensate with various geometry constraints and errors from the vision component to the object pose estimation, novel grasping strategies that exploit environmental contacts have been developed. Emphasis has been given in the development of grasping strategies suitable, for flat, directly graspable, and top reachable objects [10]. By exploiting force sensors mounted on the robot's fingertips, a method for grasp stability during transfer has been developed in order to enable gentle degradation of the system upon a failure (e.g. object fall due to a loosen grasp) [2].

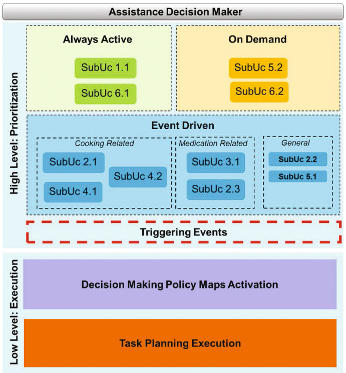


Fig. 6. The architecture of the RAMCIP cognitive functionalities

4.3 Cognitive Functionalities

The RAMCIP robot aims to address multiple use cases yet in an autonomous manner. Considering that on-board robot computational resources are limited and that the addressing of target SubUcs with diverse context is related to various human activities during the day, a *hierarchical architecture* has been embodied within the cognitive functionalities by developing an "Assistance Decision Maker (ADM)" cognitive module that decides *when* and *how* the robot should intervene to offer a coherent and relevant, proactive and discreet care solution. The hierarchical architecture of the RAMCIP robot cognitive functions is illustrated in Fig. 6. The developed architecture consists of two levels i.e. the high-level component which is responsible for the continuous monitoring of human end environment semantics through specific parameters in order to decide in which SubUc the RAMCIP robot should be engaged. The high level component also regulates the prioritization framework according to which, specific robot functionalities are always active and render RAMCIP ready to provide the respective type of intervention even if the robot is already engaged in another SubUc. In order to provide a prioritized and autonomous care solution, the RAMCIP robot continuously monitors specific parameters that sign the initiation of a target use case. This functionality comprises a deterministic part of the RAMCIP ADM which orchestrates the initiation of a necessitated SubUc, the denouement of which is undertaken by a probabilistic POMDP policy map (see Sect. 4.3) that considers observations of the environment, the human and the robot state. The target use cases (see Sect. 2) have been analysed in terms of their priority considering the operation mode namely, *always active*, *on demand* and *event driven*. Always active are the robotic functionalities that address use cases responsible for the monitoring of the user's safety and health condition. On demand, are those robotic functionalities that are emerged after user request. Event driven, are those robotic functionalities that are related to SubUcs responsible to assist in user's daily activities and are organized in three different groups with respect to the human and environment semantics. A deterministic regulatory framework has been developed, based on which a dedicated software component continuously monitors all the triggering events gathered from the robot's perception mechanism and upon activation of an event, the respective SubUc is triggered. Upon a triggering event, the low-level decision making undertakes the denouement of the scenario.

Decision Making Policy. The first component of the low-level ADM architecture is responsible to provide a suitable intervention policy, which the robot should follow in order to resolve the assistance scenario imposed by the respective SubUc. To achieve this, a dedicated mechanism has been developed based on the Partially Observable Markov Decision Process (POMDP), which is able to model the uncertainties stemming from realistic situations. The justification of such selection relies on the fact that complete situation awareness from the robot is not feasible, since the environment should be constantly monitored with limited robot sensors and the acquired sensor observations are noisy. Therefore, the robot belief uncertainty about the current state of the human, the environment and the robot itself should be broadened. For each SubUc, a handcrafted POMDP model has been designed which produces a specific policy map as described in [14]. Each state of the POMDP model corresponds to a robotic action or the activation of a perception module. Upon execution of the selected action, the RAMCIP perception mechanism observes the alterations in the environment, associates them with the policy map and the next best robotic action is selected until the finalization of the scenario. To create a comprehensive POMDP model, an exhaustive finite state machine (FSM) has been developed for each SubuUc. Each FSM was then modeled as POMDP model and by exploiting a dedicated solver [18], a policy map was created for each SubUc. An example of such FSM is illustrated in Fig. 7, where each state corresponds to a state in the policy map and is associated with a specific robotic action.

Task Planning. The robot task planner is responsible to implement the developed robotic skills, in accordance to which each selected action from the POMDP corresponds to a software component that realizes the respective functionality. Thus, the developed task planner comprises a skills library that directly interfaces with the policy map of the POMDP. The skills library has been developed with the ROS framework exploiting the intra-node communication functionalities, (service calls, actions, topics, etc.) to allow continuous operation and repeatability of each skill and scenario. Considering again the state diagram of Fig. 7, it is exhibited that each state is associated with a specific robot action. The states marked in blue color correspond to drastic robotic intervention including navigation, manipulation and grasping. The states in green color indicate perception functionalities of the robot, required for the monitoring of the environment and the user. States in magenta color are related to the communication modalities, while red colored states are control points in the scenario that allow fail safe mechanisms and re-initialization of a problematic robotic action due failures.

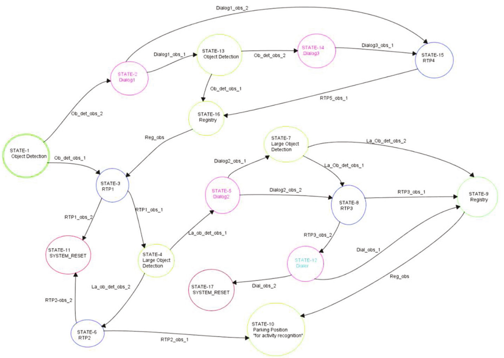


Fig. 7. An example of an FSM that is utilized for the construction of a POMDP model. (Color figure online)

5 RAMCIP Robot Installation in Pilot Trials

The RAMCIP robot has being evaluated in real house environments with MCI patients. Two robots have been prepared to operate in parallel. The first one is deployed at a simulated room of Medical University of Lublin Poland, where the robot capabilities are assessed with 20 participants and each user interacts with the RAMCIP robot for at least 3 days. The second robot, has been moved to Barcelona, Spain to be evaluated with 12 participants. Each participant interacted with the robot at her/his own house for at least 7 days. Preliminary results of Barcelona pilot site are reported herein. The robot installation at each participant's house involves one day of transportation and deployment. The deployment procedure concerns both robot preparation to operate in the specific environment as well as familiarization of the user with the robot. The robot preparation requires the environment mapping and the construction of the hand-crafted hierarchical semantic model, to denote supporting surfaces, robot parking positions for the large object manipulation, and relations of small and large objects. Familiarization of user regarding the robot concerns short demonstration of its capabilities and introduction to the communication framework. Alongside, the necessary user measurements are taken by the robot, related to biometric information necessary for user identification, affect-related baseline data etc. Overall robot's software was designed in a way that minimum invasions would have to take place at the participants' houses. In situations that the robot was not to execute a scenario due to environment restrictions, i.e. grasping of a fallen object in a very narrow kitchen area, this skill was excluded from the task planner and the ADM steered the scenario flow by exploiting solely the communication modalities; i.e. notifying the user of the event, stimulating her/him to resolve it and monitoring the user accordingly. During the pilot trials, the robot has been exposed to all the SubUcs described in Fig. 2, more than one times. In order to keep track of the evolution of the scenarios, two peripheral tools have been utilized. An external camera with video recording has been employed to capture the entire interaction among robot and human during to the exposure of the robot at each scenario. These video recordings were kept as ground truth for the evaluation of the examined scenarios. The second tool is a logging framework that kept track of the ADM's executed policy file that registers the robotic executed actions, utilized perception modules along with the exchanged communication messages, in order to be compared with the ground-truth data (video recordings). Table 1 summarizes the total number of repetitions of each SubUc and outlines the correct executions, where the scenario was successfully completed. The majority of the erroneous executions are referred to the situations where the scenarios ended-up to a "System-Reset" state of the ADM, as part of failure of a subordinate component, i.e. the robot was not able to reach its target location after N attempts due to localization errors. Figure 8 exhibits the RAMCIP robot interaction with the user or the environment in different apartments, for each one of the target SubUcs.

Table 1. Preliminary evaluation results of the RAMCIP robot during pilot installation in Spain.

SubUc	Total executions	Erroneous executions	% Correct execution rate
SubUc 1.1	15	1	93.33
SubUc 2.1	31	7	77.41
SubUc 2.2	16	2	87.5
SubUc 2.3	31	4	87.09
SubUc 3.1	17	3	82.35
SubUc 4.1	20	3	85.00
SubUc 4.2	26	3	88.46
SubUc 5.1	18	1	94.44
SubUc 5.2	16	2	85.71
SubUc 6.1	26	3	88,46

Fig. 8. Examples of RAMCIP interacting with users and the environment during the preliminary trials. Top row: SU1.1 (emergency), SU2.1 (turning off electric appliances), SU2.2 (turning on the light), SU2.3 (detection of improperly place objects), SU3.1 (medication bringing). Bottom row: SU4.1 (assistance upon detection of abnormalities during cooking), SU4.2 (assistance for fallen objects), SU5.1 (proactive bringing bottle of water), SU5.2 (on demand bringing a snack), SU6.1 (provision of cognitive training).

6 Discussion

In this paper we presented the multidimensional approach needed for the development of a domestic assistance robot for patients with MCI. The process varies from the establishment of users requirements, to integrating social and empathic aspects into the basic components of the robotic platform. Human, environment, and activity monitoring have been employed so that RAMCIP can combine information about its environment, its user and her/his tasks, enabling it with the ability to provide proactive assistance by integrating these technologies under one single robotic platform. The preliminary results from the pilot trials in Barcelona indicate that the RAMCIP prototype can successfully accomplish its core tasks and provide assistance for the target group within the rather challenging environments of real end-users homes. Even if, in some limited cases, users may have initially approached the robot with uncertainty and doubt on its ability to be helpful and assistive, RAMCIP was able to interact with all participants and their house environments, by performing all of its target tasks, leading to a final positive assessment in terms of its usability and acceptance.

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