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Project Abstract

The RAPP project will provide an open-source software platform to support the creation and delivery of Robotic Applications (RApps), which, in turn, are expected to increase the versatility and utility of robots. These applications will enable robots to provide physical assistance to people at risk of exclusion, especially the elderly, to function as a companion or to adopt the role of a friendly tutor for people who want to partake in the electronic feast but don't know where to start.

The RAPP partnership counts on seven partners in five European countries (Greece, France, United Kingdom, Spain and Poland), including research institutes, universities, industries and SMEs, all pioneers in the fields of Assistive Robotics, Machine Learning and Data Analysis, Motion Planning and Image Recognition, Software Development and Integration, and Excluded People. RAPP partners are committed to identify the best ways to train and adapt robots to serve and assist people with special needs.

To achieve these goals, over three years, the RAPP project will implement the following actions:

- Provide an infrastructure for developers of robotic applications, so they can easily build and include machine learning and personalization techniques to their applications.
- Create a repository, from which robots can download Robotic Applications (RApps) and upload useful monitoring information.
- Develop a methodology for knowledge representation and reasoning in robotics and automation, which will allow unambiguous knowledge transfer and reuse among groups of humans, robots, and other artificial systems.
- Create RApps based on adaptation to individuals and taking into account the special needs of elderly people, while respecting their autonomy and privacy.
- Validate this approach by deploying appropriate pilot cases to demonstrate the use of robots for health and motion monitoring, and for assisting technologically illiterate people or people with mild memory loss.

The RAPP project will help to enable and promote the adoption of small home robots and service robots as companions to our lives. RAPP partners are committed to identify the best ways to train and adapt robots to serve and assist people with special needs. Eventually, our aspired success will be to open and widen a new 'inclusion market' segment in Europe.

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List of Abbreviations

Abbreviation	Definition
RAPP	**Robotic Applications For Delivering Smart User Empowering Applications**
RApp	**Robotic Application**
GAADRD	**The Greek Association Of Alzheimer Disease And Relative Disorders**
MCI	**Mild Cognitive Impairment**
QoE	**Quality of Experience**
10mWT	**10 Meter Walking Test**
TUG	**Time Up and Go**

Executive summary

The present document is a deliverable of the RAPP project, funded by the European Commission's Directorate-General for Communications Networks, Content & Technology (DG CONNECT), under its 7th EU Framework Programme for Research and Technological Development (FP7).

D6.3.1 Evaluation of the pilot RApps belongs to Work Package 6, Evaluation part and is an early report on the evaluation of the first developed RApps. It will be followed by its second and comprehensive version (D6.3.2) at the end of the project after full pilot trials during the last year of RAPP.

This document shows the current status of the prototypes and RApps development for both NAO and ANG-med and the preliminary testing that are being carried out in order to ensure the correct performance and integration of all elements needed to run the defined scenarios (D4.2), before the long term pilot trials that will take place at Ormylia and Matia.

Section 1 summarizes the first developed and implemented scenarios, Send Mail and Cognitive Games for NAO, and Dynamic and Static exercises for ANG-med. Section 2 describes the developed prototypes and RApps. Section 3 includes the methodology and testing tools used to evaluate these first RApps and finally Section 4 describes the early results obtained by Ormylia with the NAO robot and by INRIA with the ANG-med rollator.

Introduction

During the first year of the RAPP project target users and their profile have been defined, and both robots NAO and ANG-med have been presented to them in order to derive their needs and requirements. Meetings, focus groups and interviews have been carried out in Ormylia and Matia and have allowed us to define and describe the use cases for the three different target groups (Table 1). At the same time, we were able to gather the user requirements that have been translated to functionalities for the robots. The work done so far has been described in detail in the previous deliverables of WP1 and WP4 (D1.1, D4.1 and D4.2).

User group	Use case/Functionality	Robot
Technology Illiterate People	• Hazar detection • Sending e-mails • Calendar/Important dates and events • Skype calls	NAO
People with mild cognitive impairment	• Hazar detection • Medication alerts • Calendar/Important dates and events • Memory ball • Cognitive games	NAO
Mobility assistance and activity monitoring	• Correct position • Dynamic exercises • Static exercises	ANG-med

Table 1. RAPP scenarios and use cases

Following the description of the use cases, the first RApps were developed and implemented according to their importance and feasibility priority (Table 2).

RApps	Target User Group /Scenario	Robot	Evaluated by
Send Mail	• Technology illiterate people	NAO	6 illiterate seniors
Cognitive Game	• Technology illiterate people	NAO	6 illiterate seniors
	• People with cognitive impairment		Not evaluated yet *
Dynamic walk exercises: - 10m walking - Time Up and Go - Inverted L - Maze	• Mobility assistance and activity monitoring	ANG-med	5 subjects of Hephaistos research team of INRIA
Static execises: - Hip extensión - Hip abduction - Plantar flexion - Hip flexion	• Mobility assistance and activity monitoring	ANG-med	5 subjects of Hephaistos research team of INRIA
Position determination	• Mobility assistance and activity monitoring	ANG-med	5 subjects of Hephaistos research team of INRIA

Handle pressure	• Mobility assistance and activity monitoring	ANG-med	5 subjects of Hephaistos research team of INRIA

Table 2. Developed and implemented RApps

This document describes the current status of the developed elements (hardware, firmware, software, interfaces, applications and others) which are being integrated and implemented in the robots, that is to say the preliminary prototypes. It also describes the early evaluations that have been carried out with those prototypes, both from a technical and user-system interaction point of view, to examine whether the prototypes function correctly and are able to i) perform the defined use cases and ii) measure the required indicators.

The early RApp prototypes addressed to a) the groups of Technology Illiterate users and b) the users diagnosed with MCI have been both tested with NAO at the Seniors Center. We have exclusively used the technology illiterate focus group for a number of reasons: it was easier to be controlled and evaluated as we have been working with them during the last year and are keen to the idea of using robots; NAO could understand but not speak Greek, a difficulty that could be easily manipulated in this group; the lack of Greek was a barrier for MCI users. Although pilot testing of RApps with MCI users has been postponed, it will be definitely performed as soon as the language issue will be solved.

The early RApp prototypes addressed to mobility assistance and monitoring using the ANG-med rollator, rather than being evaluated by older people, have been evaluated by researchers at the Hephaistos lab of INRIA to ensure their correct functioning and safety before their whole implementation to the large pilot trials.

There will be an update of this deliverable (D6.3.1b) by the end of the year and before the next review to show the progress on the evaluation of RApps with end users (researchers, caregivers and older people). The final and complete evaluation report (D6.3.2) will be delivered in M36 after the large pilot trials.

1. Integrated scenarios description

1.1 Technology illiterate people

Isolation and social exclusion are some of the issues that are tormenting older people as getting older comes with a number of facts which shrink their social environment: retirement and exit from the labour market disconnect elderly from their colleagues and friends at work or even from a rich social context of clients and fellow market workers; their sons and daughters have created their own families and live in a distance that sometimes is quite long; Adding to the above some early losses of friends and relatives makes clear that ageing is getting seriously challenged by social exclusion. Communication is crucial to keep in touch with their social cycle and in such a case we cannot leave out of the plan computers and Internet.

Most of the seniors did not use computers in their workplace before retirement and Internet might sound as a vague and unknown territory. Moreover, physical and cognitive issues that come with ageing could make learning and using of computers difficult. Still, and despite the difficulties, seniors are increasingly adopting computers and the Internet [1]. RAPP aspires to go one step further and make technology and Internet available for all seniors despite their physical and cognitive situation by using applications for robots that function as companions and assistants. A number of use cases and scenarios have been described in Deliverables 4.2 and 5.1.1. To initiate their evaluation in a primary stage and detect possible faults and bugs, we have chosen the scenarios of ***emails sending*** through the robot and train attention and memory through ***cognitive games*** performed by the robot. The interaction between the elderly and the robot is evaluated in terms of acceptance, perceived user comfort and Quality of Experience (QoE).

The user group of technology illiterate elderly was chosen for both pilot testing scenarios. We preferred to initially address only this group for a number of reasons, such as: a) both robotic applications (RApps) of ***Send emails*** and play ***Cognitive Games*** can be addressed to both of our user groups (technology illiterates and suffering from Mild Cognitive Impairment); b) the group of technology illiterate elderly has been attending technology classes for more than a year and they are familiar at this point with computers and robots facilitating the comparison between these two options; c) NAO, the robot we are using, can understand Greek but does not speak Greek but it cannot currently talk in Greek (a technical shortcoming that will be addressed in an upcoming version update) which makes it difficult to test it with MCI elderly as it would provoke user's discomfort and withdrawal from tests.

Send emails and ***Cognitive Games*** scenarios were selected to be initially tested as they are addressing two major subjects of the seniors' daily life: communication and fun through training.

1.1.1 Send Mail scenario

Communication and information are both crucial for elderly people. Whether living alone or not, at home or at a nursing home, the need to communicate with their family, friends and the society is very important. The ability to send a message to their children or receive a photo from their grandchildren at any time of the day is precious. The option of communicating through email with public services or private service providers make seniors feel self-confident and having control on their lives.

The user group of technology illiterates at the Seniors Center of New Moudania has stated in our regular meetings that communication is very important for them and they would like to stay in touch with family and friends by using "new technologies" such as email and Skype. They all have family members or friends who live in different cities or countries and calling them through telephone is not always easy as they would not like to interrupt their children from working or studying and phone calls are sometimes very costing, especially when they call abroad. When they started to attend RAPP technology classes they didn't know how to use a computer but they were eager to learn, particularly how to send an email. Despite some physical difficulties (vision problems, arthritis etc) they never missed a class and 15 months later they are able to use a laptop and email services. As they are not still independent users but need a little help or reminding them parts of the procedure, the Send email RApp through NAO is going to be an alternative that will facilitate their communication without an effort or prolonged training.

NAO is going to realize this application, which the elder can follow with some simple steps. After initializing the application on NAO (oral order), the senior will pronounce his message to the robot which will record it and attach it as a sound file on a new email. The robot will ask from the senior to define the time duration of the message (there is a fixed timeout value of two minutes for capturing user's speech) as well as to identify the recipient(s) from a predefined list. Then the robot will confirm with the elder and send the message. When a mail is received, the robot will be able to pronounce it to the elder via an embedded text to speech application or reproduce it in the case of a sound file.

The Send Mail RApp allows the application users to easily send an email to a desired address. They don't have to use a keyboard to write their message or a computer mouse that usually tricks them with "left click – right click". These were actually some of the actions that dishearten them in our meetings as they were writing slowly when using the keyboard and computer mouse was difficult to handle by those suffering from arthritis. The computer mouse pad could be a solution but complicated activities as moving through text or copy-paste and others were also tricky.

The Send Mail RApp requires the following inputs in order to successfully send the requested email:

- *Sender address*: Sender email address (From). Current implementation has a predefined sender address for each user that is automatically loaded from the RAPP Platform.
- *Recipient address*: Recipient email address (To). Current implementation has a predefined recipient address for each user that is automatically loaded from the RAPP Platform.

The Send Mail RApp procedure is very simple and is illustrated in the following Figure 1:

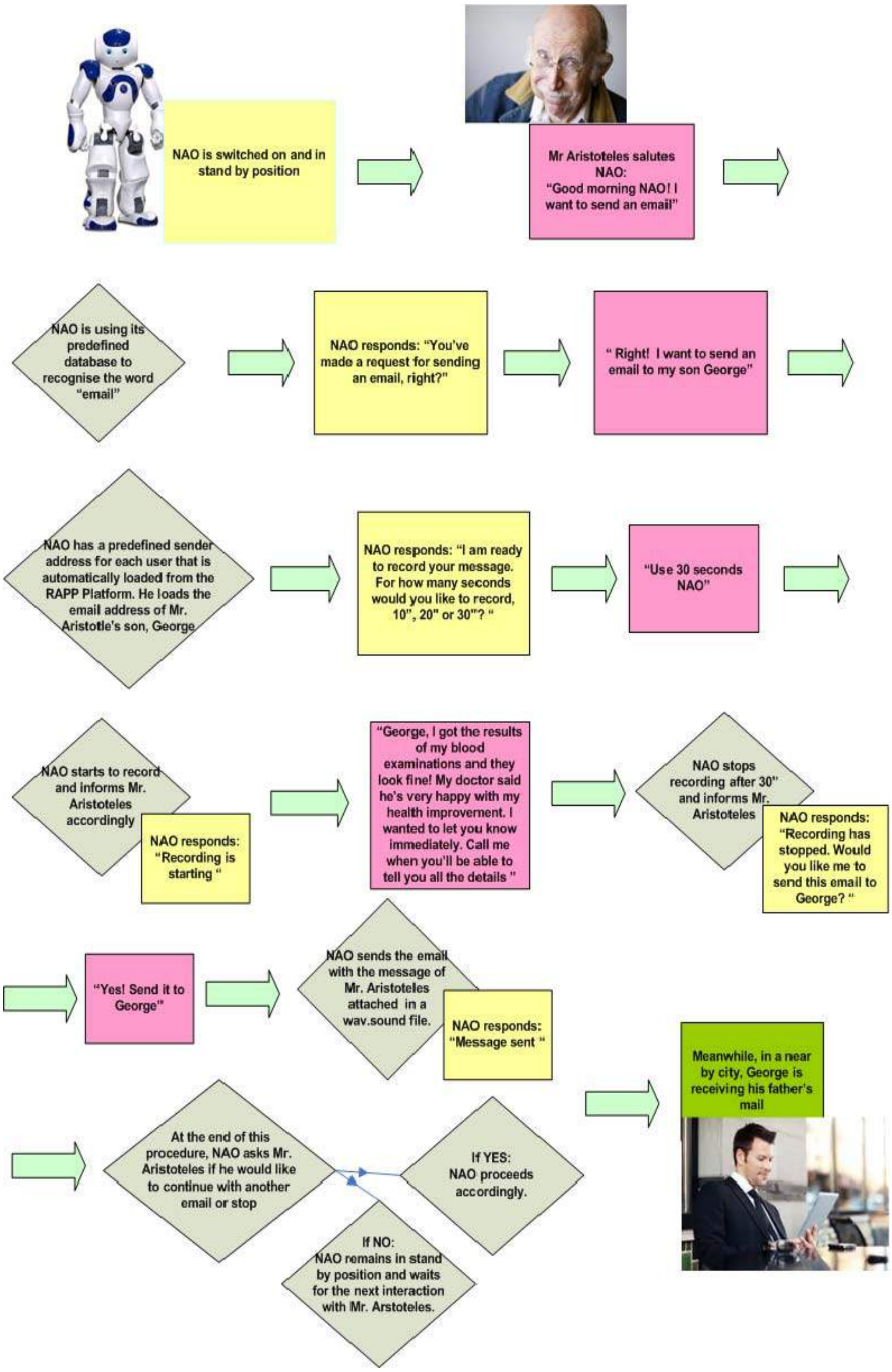

Figure 1. Send Mail Scenario

1.2 People with MCI

Mild Cognitive Impairment (MCI) is a term used to characterize a pre-dementia phase or an intermediate diagnosis between normal cognitive function and dementia [2]. A small but noticeable decline in cognitive abilities can be detected including memory and thinking skills [3]. Still, people with MCI can live independently, drive and have an active presence in their social environment. What differentiates MCI from normal ageing forgetfulness is the tendency to forget more than usual important dates like doctor's appointments or important social events, mix up the sequence of doing tasks that have multiple steps, inability to recall recent events, losing orientation in familiar places, failure to judge time needed to solve a problem and take sound decisions. Not all people with MCI will develop dementia but they are in high risk of developing Alzheimer or other forms of dementia [4].

Usually, the symptoms are noticed both by the affected persons and their family. People diagnosed with MCI feel frustrated, tend to hold back from their normal life and isolate, leading to the deterioration of their cognitive status. In some cases, a pharmacological treatment is suggested but is widely accepted that physical and cognitive training can maintain the physical and cognitive status of the person and delay or stop the progression of MCI. According to Belleville [5], cognitive training optimizes cognitive function in elderly diagnosed with MCI. There is more research evidence suggesting that cognitive training can improve the cognitive function in healthy seniors and delay cognitive decline in seniors diagnosed with MCI [6], [7]. People suffering with MCI should maintain their social life and avoid isolation. Isolation and social exclusion can only deteriorate their physical and cognitive condition due to the lack of stimuli (both physical and psychosocial). Healthcare interventions should focus on prevention and treatment in the daily environment of the seniors, keep them active and socially effective [8].

1.2.1 Cognitive Game scenario

In the context of RAPP project, we have been attending the daily activities of the Greek Association of Alzheimer Disease and Relative Disorders for almost a year. As volunteers we had the opportunity to attend both diagnostic and cognitive training sessions. We observed that training sessions used a number of cognitive games to assist attention and improve memory and among them short story telling or reading was used more often to: be recalled later as an abstract of the story, spot and separate specific words in the text, count specific words or use them to make your own story. The use of short stories was pleasant for the participants as they had a meaning that they could process, they were easy to use in the time frame of the sessions without getting anxious or bored and they could connect them with personal experience and knowledge to recall them later. Apart from the fun part of this procedure, seniors who attend these sessions, maintained and improved not only their cognitive health but also their psychological status as they were exercising in groups, in a friendly and supportive environment. They were competing and tease each other during sessions, laugh with their own scores when they were bad, ask from the trainer to repeat the exercise and get a better score ("Have you finished your test? I finished first!", "How many words did you find? Fifteen? Are you sure? I found only ten…", "If I'll finish first you'll buy the coffees").

As a result of the above experience at the Greek Association of Alzheimer Disease and Relative Disorders, we gave priority to build the Cognitive Games scenario. NAO will perform as the training companion offering short story telling. Seniors should attend carefully and recall them later to answer a number of questions associated with the story. After each story session the robot will store the answers to the cloud and keep them available both for the elderly and any caregiver or therapist with the necessary permissions. The elderly will be able to repeat the same session and improve their scores or choose a new session. For the pilot testing we used a simple story (Figure 2 and Annex 1) and ten (10) questions (Q&As) that could be answered with a YES or NO (closed questions), while any other answer was not recognized and therefore NAO requested from seniors to repeat the answer. At the end of the game, NAO announced the total score which according to the results could be: "*Well done, you answered 7 out of 10 questions right! Keep exercising*" or *"It seems that you need to play more cognitive games. You got 4 out of 10 questions right".* This cognitive game is going to be enriched with more stories in different levels of difficulty that could range from simple narratives to history or scientific texts. The scope of this RApp is to create a fun activity that will train seniors and maintain their cognitive and psychological health. The RApp could be used by all seniors (healthy ageing or diagnosed with MCI), their caregivers, professionals and trainers in cognitive health associations and centers and researchers in the field of robotic applications for elderly.

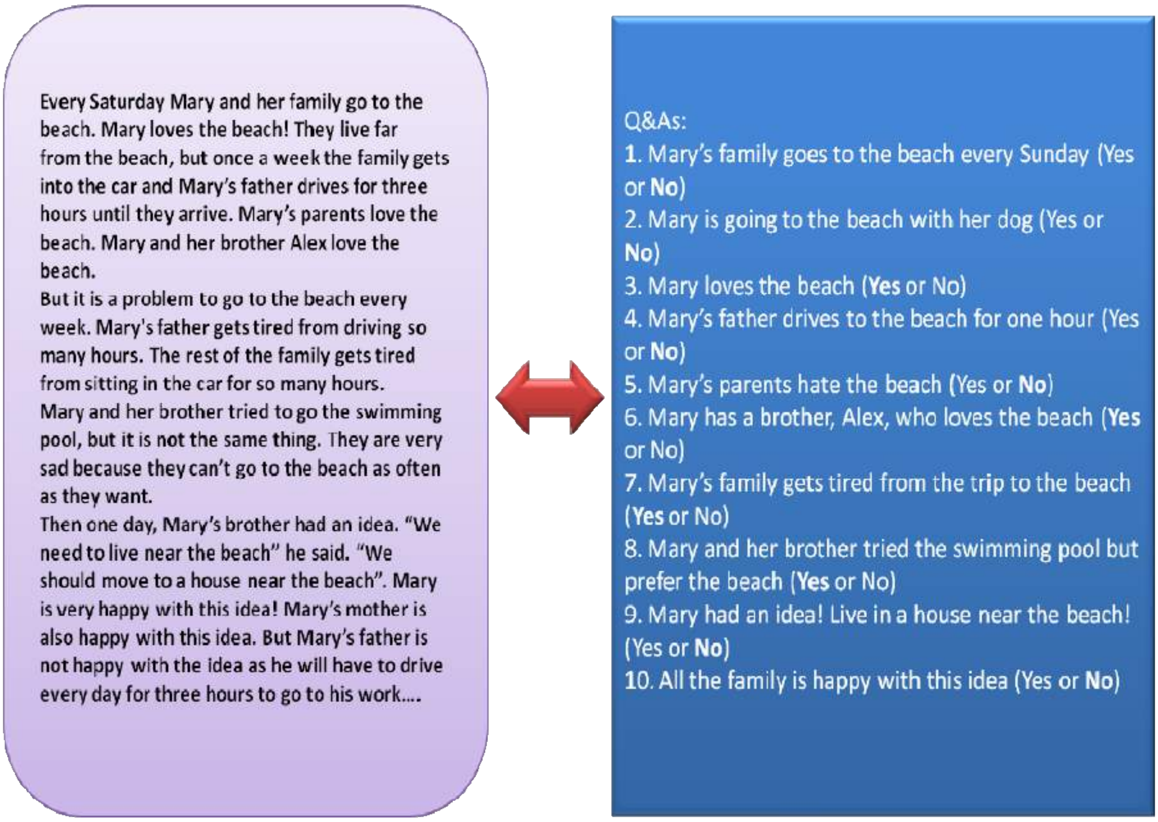

Figure 2. Cognitive game (Q & As)

Important note:

The Cognitive Game scenario was tested with the group of the technology illiterate seniors. As NAO is still not eligible to speak in Greek, pilot tests could not be performed at the Greek Association of Alzheimer Disease and Relative Disorders. We should translate in parallel with the execution of the game and this could create confusion and discomfort to the users. As the specific users (both patients and their therapists or caregivers) are a very sensitive group, we decided to postpone testing until the next version update of NAO and the availability of Greek language.

The Cognitive Game RApp procedure is illustrated in Figure 3.

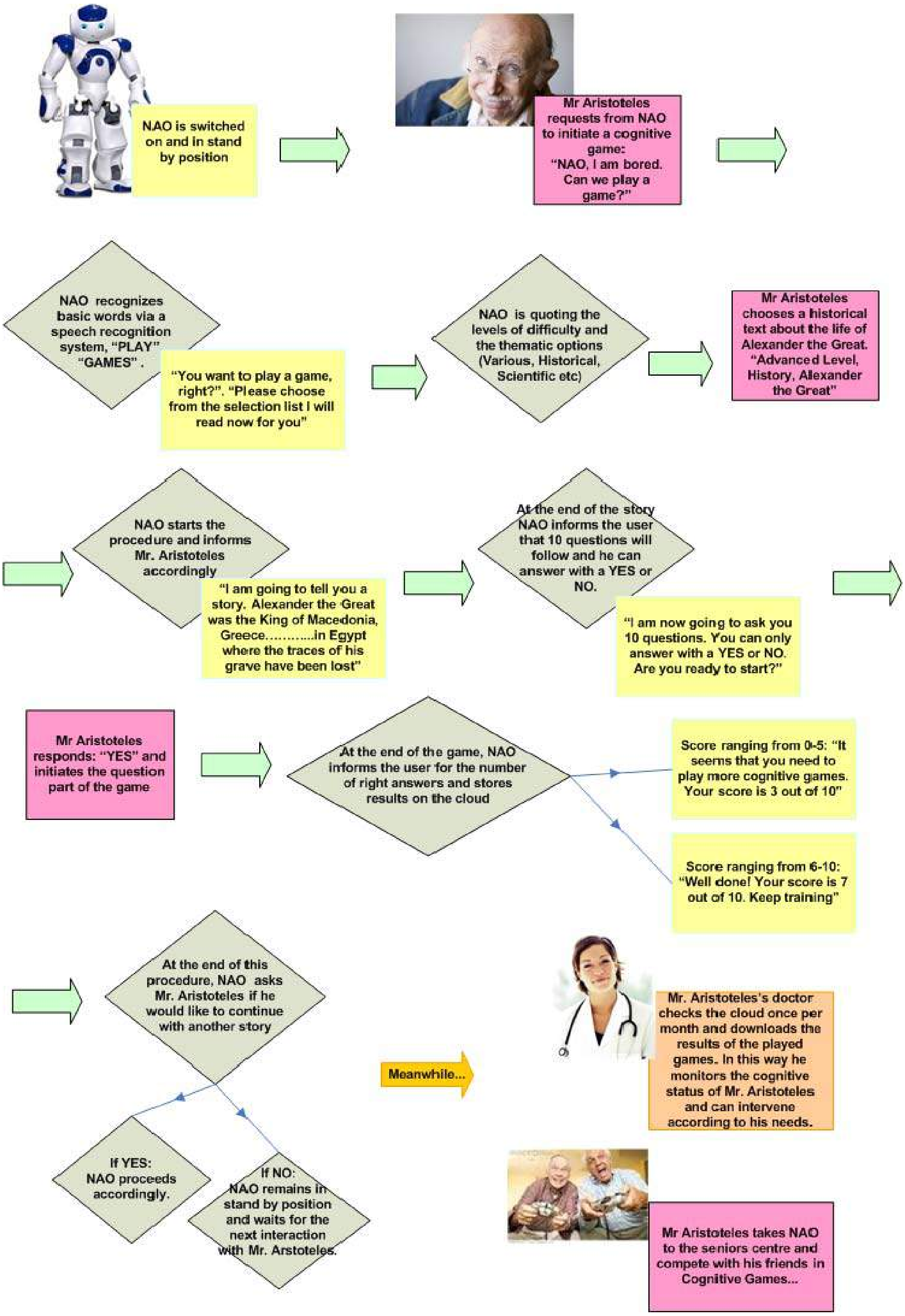

Figure 3. Cognitive Game Scenario

1.3 Mobility assistance and activity monitoring

The objective of the Rollator application is to customize the ANG-MED rollator to enable its use during rehabilitation exercises, as specified by MATIA caregivers and users.

The application will ultimately provide services:

- to the caregivers, letting them authenticate themselves, securely operate and control the rollator, manage user records and activity data (real time and offline monitoring).
- to the patients, allowing the automatic personalization of the ANG-MED to the user's needs (calibration, rehabilitation program), and providing a suitable user interface during the exercises and appropriate feedback when the exercises are completed.

The application consists of embedded software on the ANG-med, and additional services hosted on a remote (cloud) platform. The interaction between the user and the ANG-med is done primarily through the ANG-med sensors and effectors. The caregiver uses a dedicated infrared remote command to control ANG-med.

The caregiver also interacts both with the cloud services and ANG-med using a web application on a PC control station (or a tablet).

The patient may also use the tablet: a dedicated user interface supports the patient and family along the rehabilitation steps by providing information about the work programme, past achievements and next objectives (all in a positive way).

The complete setup consists of the ANG robot, an infrared remote used to directly control the robot, a PC control station used by the caregiver to operate the robot and access to activity data, and the RAPP platform which hosts the RAPP store (directory of program files that can be installed on the robot and on the platform as remote services), the remote applications (once installed from the RAPP store) and the platform services used by these applications (in our case, the authentication/authorization services, the database of activity data, and the server application for the PC control station).

Caregiver access to the control station web application is protected by a login and a password.

Users wear optional RFID wristbands for automatic identification.

The ANG robot software consists of:

- A Linux OS core.
- The ANG firmware (collection of C, C++ programs and drivers). The firmware controls all the hardware (sensors, brakes, led(s), and the IR remote). The firmware is in charge of detecting the user presence, analyzing the user posture, calibrating the robot, controlling the execution of exercises, synthesizing higher level messages from sensors during robot activity (through signal processing and algorithmic procedures applied to raw data). The firmware also logs activity data into files written locally on the robot and make them available to the RAPP for exploitation.
- The embedded RApp. The RApp is developed in HOP (JavaScript). The embedded RApp is part of the complete RApp which is actually distributed across the robot and the RAPP platform. The embedded RApp is in charge of all communication aspects (to and from the robot), additional processing on activity data before these are sent to the platform (and optionally to the control station for real time monitoring), controlling some features of the firmware (application selection, calibration steps, complementing the IR remote). The embedded RApp may also contain control scripts that modify the robot configuration or the robot dynamic state depending on the current application scenario. The embedded RApp is subdivided into a coreagent that is running whatever the application scenario is, and a dynamic agent that is downloaded and installed from the RAPP store.

The firmware and the embedded RApp communicate by exchanging messages using the ROWE protocol. They may also communicate indirectly through the file system (for example to upload/download calibration files).

The ANG robot software uses the generic RAPP Platform services provided from:

- Cloud Agent.
- RAPP Platform Agent
- RAPP Store Download Application Service

These services can be invoked using the RAPP API.

The dynamic RApp for ANG-med is implemented as two agents: The embedded dynamic agent and the cloud dynamic agent.

The embedded dynamic agent is a collection of embedded scripts to: a) Locally control the ANG-MED operation through interactions with the firmware, b) Locally analyse activity data and generate events towards the RAPP platform, and c) Provide a web front end service to enable a web client (such as the PC control station) to control ANG-MED and monitor its state.

The cloud dynamic agent provides the following services: a) Web front end for the control station client, b) Management of dynamic state ANG-MED robots and active users, c) Management (database log) of messages received from ANG-MED and d) Message passing between the ANG robot and the PC control station.

The software architecture is designed to dedicate the embedded processor to real-time control of ANG-MED and uses the cloud platform resources for all the tasks that can be deported.

Development and test of the application

The current version of the rollator application does not yet involve all the components of the complete setup. Thanks to the complete specification of messages passed between the firmware and the application and of the underlying transport protocol (ROWE), ANG-MED firmware and applications can be developed and tested in parallel.

Each component is tested in a simplified mode where the component runs by itself, then additional tests are performed with software responders that emulate the missing pieces. INRIA has defined tests to validate technical components (hardware sensors, software architecture, communication protocols, security). Functional tests have also been defined. However, the integration of both components has not been performed yet, and the application features are demonstrated using an additional component that emulates the firmware and the hardware of the rollator, generating a subset of the messages that the actual firmware will deliver once integrated.

Therefore the actual setup to run the application consists in the following software components:

The firmware/hardware simulator. This component is implemented as a HOP program; it provides a simple web user interface to trigger the messages currently supported by the application. The messages are transmitted to the embedded Core agent using the ROWE protocol (JSON over web sockets).

The embedded core agent. This embedded component controls ANG-MED firmware, installs and runs embedded dynamic agents, passes messages and service requests back and forth with the RAPP platform cloud agents. The embedded core agent is implemented as a HOP program.

The RAPP store. This file server component resides in the cloud. Its purpose is to select the program files corresponding to the robot model and dynamic agents (the variable part of the distributed application), and deliver these program files to the embedded core agent (robot part) and to the cloud core agent (remote part). A simplified version of the store agent is used here.

The embedded dynamic agent.

The cloud core agent. This is the application agnostic part of the ANG-MED cloud agent. It is in charge of user profile management, data storage, installation of cloud dynamic agents.

The cloud dynamic agent provides most of the services invoked from the control station.

The control app runs on the PC control station. This is a web application (uses a standard JavaScript enabled web browser), which connects to ANG-MED and to the RAPP platform. There may be several control stations (their display is kept in sync when they control the same robot), and the PC can be complemented or replaced by a tablet or a smartphone.

1.3.1 Working modes for ANG-med

For defining the scenario we first need to distinguish different working modes for ANG-med:

- **stand alone:** ANG-med is not connected at any control station during an exercise.
- **partly connected:** ANG-med may be connected at specific moment of the exercise (e.g. at the start, when the exercise is completed or just to download a specific exercise)
- **fully connected:** ANG-med is connected at any time during the exercise

ANG-med has been designed to work in any of these modes. For the partly connected and fully connected mode a message passing mechanism based on INRIA rowe has been designed. In the fully connected mode the control station may just monitor the behaviour of the walker, may modify some exercise parameters on the fly or even have full control of the walker (although from a real-time point of view it will be less efficient that the embedded real-time of ANG-med firmware because of the communication delay). An extensive messages library has been designed and fully documented with over 400 allowed messages going from very low level actions (e.g. provide the distance measured by the left front distance sensor, set the left brake to a braking level of 70%) to high level actions (execute a given exercise and report).

Before going to exercises it is necessary to answer the following questions: who is doing the exercise? Which caregiver is possibly in charge of the exercise? For that purpose we will rely on two methods:

- **local:** ANG-med is equipped with a short range (10 cm) RFID tag reader
- **control:** the control may provide an ID through the message passing mechanism

In the local mode ANG-med is provided with specific RFID tags for caregivers and with mark tags that are intended to allow to record specific events for some exercises (e.g such a tag may be put in a specific room and the user/caregiver will have to present this tag when in the room). Any other presented tag will be assumed to be a subject tags. ANG-med is provided with a tag dictionary so that when a RFID tag is presented it will be able to determine if the tag corresponds to a known subject, a caregiver or a mark. Any new RFID tag that is not a caregiver or a mark tag will be assumed to be a new subject. This will create automatically a new repository so that we can store specific parameters for the new subject.

A similar behaviour may be obtained when the ID is sent by the control.

In any of the modes the walker may execute pre-defined exercises that are resident on the walker PC. ANG-med firmware has been designed so that executing pre-defined exercises will allow taking full advantage of the real-time ability of the firmware. Such exercises are defined as a set of messages so that new exercises may be downloaded later on.

As soon as an exercise involves a monitoring part the walker will follow closely the execution of the exercises. For that purpose it will write records and will provide exercise indicators.

Exercise indicators are synthetic information, usually numbers, which are intended to provide a global overview of the execution of the exercise. There are usually reported at the completion of the exercise. Records are intended to be post-processed after the completion of the exercise in order to provide additional indicators about the exercise possibly after an extensive analysis that may be computer intensive (record files may be huge).

Records and indicators are encrypted and are not associated in the walker PC to any user name in order to preserve the confidentiality of medical data.

We have also defined access level for the indicators. Some of them will be available for anybody, some of them only to formal caregiver. As for the records they are usually not available except for specific users.

1.3.2 Specific elements

Before going on with the exercise it is necessary to present two elements that are specific for the walker:

- **Subject position:** a subject may be too far or too close from walker. The too far position may be dangerous as it may lead to a fall of the subject while a too close position leads to an incorrect use of the walker. For detecting the subject position ANG-med is equipped with adjustable rear looking distance sensors that measure the position of both legs of the subject. ANG-med has a standard orientation for these sensors but a calibration procedure may be used to accommodate specific subjects. This calibration has to be run only once and its result will go in the user profile.
- **Pressure on the handle:** ANG-med is able to determine how much pressure is exerted on each of the handles without using force sensors. However this information will be available only if the system has been calibrated for the subject. Here again the calibration has to be run only once as the result are stored in the user profile.

1.3.3 Pre-defined Exercises

MATIA and INRIA have worked together to define exercises that may be of interest for the users and clinicians:

1.3.3.1 Dynamic walk

The purpose of this exercise is just to record the activity of the subject during the day. Hence the trajectory and the travelled distance of the walker during the day are recorded.

In addition to the distance covered each day and time needed, it is very important to register the quality of the activity by means of recording the positioning of the user with regard to the rollator and the force applied with hands on both handles.

The indicators provided will be the travelled distance, the exercise duration, the mean and maximal speed of the walker, the maximal angular speed, the mean position of the subject and the mean handle pressures. Post-processing will require having a map of the environment so that the caregiver will be able to follow exactly the motion of the subject in this environment together with the timing of the motion. This will probably be the most often used exercise and hence it has been designed to run as a default exercise: ANG-med automatically will run the dynamic walk when started.

The scenario of a daily walk is described below:

Steps	Dynamic exercises scenario	Notes
0	The patient can be alone. The rollator is in the patient's room, in standby, full battery. Brakes are off.	
0.1	An objective of distance is presented in smooth form in the tablet installed in the room of the patient	
1	The patient holds the rollator, ANG-MED is activated	
2	Identification of the patient by an RFID tag ANG informs that *"all is ok", all apps are already loaded*	This uses common RAPP apps
3	The apps dynamic exercise is loaded by default. Patient doesn't need to press any button to start the exercise	
4	The patient performs his/her walk	
5	The patient presses a button to stop the "dynamic exercise" or The dynamic exercise stops if the rollator is not moved for xx seconds	
6	ANG sends data to RAPP	ANG computes directly the indicators and send them to RAPP
7	The information about patient walk is presented in a smooth form on the tablet for the patient and informal caregiver	
8	The information about patient's walk is presented in a professional form to the formal caregiver on the PC or Tablet	
9	The caregiver is invited by RAPP server to adjust the objective distance for the patient	

Table 3. Dynamic exercises scenario

1.3.3.2 Static exercises

Hip flexion: The hip flexors are a group of muscles that help people flex or move their leg and knee up towards their body. The hip flexion exercise will strengthen those muscles and let people raise the knee, for example to climb stairs or get on a bus. The rear looking sensors are used to monitor this exercise. The indicators are the number of hip flexions, their minimal, maximal and mean duration, amplitude and several other statistical data about the execution of the flexion.

Figure 4. Hip flexion

Hip extension: The hip extension exercises will strengthen the gluteus, which are the second most important muscles for standing, walking and climbing stairs. The indicators are the same than for the hip flexion.

Figure 5. Hip extension

Hip abduction: This exercise strengthens the side muscles of both hips which will lead to stabilization of the pelvis when walking and thus a safer walking and a smaller residual lameness after surgery. Although this exercise has not yet been fully implemented preliminary test leads, described in section 4.3.4, us to believe that it will be available for the long term test.

Figure 6. Hip abduction

Plantar flexion: This exercise will improve ankle mobility and strength, which is essential to walk in any surface and to support body's weight. This exercise has been implemented and preliminary evaluation is described in section 4.3.4

Figure 7. Plantar flexion and dorsiflexion

The generic static exercise scenario is shown in Table 4:

Steps	Apps Static exercise scenario	Notes
0	The patient can be alone (after 2-3 days). The rollator is in the room of the patient, powered or in stand by.	
0.1	Identification of the patient by an RFIG tag ANG informs that *"all is ok", all apps are already loaded*	This use common RAPP apps
1	The patient presses a button on ANG to start the static exercise The apps static exercises is loaded	The number of times that each exercise has to be performed is loaded
2	Successively, for each exercise :	
2.1	On a table, a picture (a movie) shows the correct posture and movement that the patient has to perform.	Ang validates the movement
2.2	The step 2.1 is repeated N times as a function of caregiver's instruction	
2.3	The next exercise is loaded	
3	The end of exercise is noted	
4	Ang computes a score	
5	Results are presented to the patient in a simple form (non numeric form, a picture for model very good, good, average, bad …) via tablet	
	Results are presented to the caregiver via a computer in professional form	
6	The caregiver can change the number of times each exercise has to be done	

Table 4. Static exercise scenario

1.3.3.3 Other interesting exercises

INRIA's experience on mobility analysis has led us to add classical exercises that are used for mobility assessment but for which the use of the walker provides more objective measurements and additional data that have been shown to be medically relevant. These exercises has also been developed for ANG-med and implemented:

10m walking: the subject has to walk 10m in a maximal straight way [9]. The indicators are the distance travelled, the time, the maximal speed, the maximum of the lateral deviation. Additional indicators such as number of steps, pressure on the handle are obtained with the post-processing.

Time up-and-go (TUG): the subject start seated, stand-up, walk 3m in straight line, performs a turn around, walk back to the seat and seat [10]. The indicators are the time and the travelled distance. Post-processing allows obtaining additional indicators such as the surface needed to perform the turn-around.

Inverted L exercise: this exercise is similar to the 10m walking exercise except that the trajectory has the shape of an inverted L, i.e. it includes a straight line trajectory of 5m, a left/right turn, a straight line trajectory of 5m, a turn around, then a straight line trajectory of 5m, a right/left turn and a straight line trajectory of 5m to come back to the starting point. The indicators are the same than for the 10m walking exercise except that post-processing will allow obtaining pertinent medical data for the manoeuvre part of the trajectory, especially the turn-around.

Maze: the subject has to move in a given environment with multiple obstacles from a starting point to a goal point while avoiding the obstacles. The indicators for this exercise are the time, the travelled distance and the minimal distance between the walker and the obstacles.

2. Prototypes and RApps description

2.1 Send-Mail and Cognitive-Game via NAO robot

The prototypes follow the Early RApp implementations as presented in D5.1:

- Send Mail via NAO robot.
- Story Telling and Q&A via NAO robot – Cognitive Game.

In this document we will address the implemented pilot RApps as *Prototypes*.

Furthermore the *Story Telling and Q&A via NAO* prototype has been renamed in a way more suitable to its application. In this document we will address it as the *Cognitive Game via NAO prototype,* or in a more simplified form, the *Cognitive Game RApp/Prototype.*

The prototypes of the Send Mail via NAO, and the Cognitive Game RApp(s) employ the core functionality of the RAPP System. This means it utilizes the RAPP Platform and the NAO Platform API's already developed in order to execute specific tasks. The control system is split between the robot embedded and the cloud computational resources.

More specifically, the RAPP Platform components which have been used in the prototype are:

- <u>*Speech Detection module*</u>: The speech detection module is located on the RIC (RAPP Improvement Center) and it is used to translate voice audio input into a dictionary of words. This module is based on the Sphinx4, which is a speech recognition library. It provides technics to convert the speech recordings, obtained from the NAO microphones, into text.

- *Speech Detection web-broker service*: In order for NAO to communicate with the RAPP Platform, a broker web service, based on hop, has been implemented as a prototype. This service actually handles requests for the Speech Detection module, as a part of the RAPP Improvement Center. The prototype has been implemented in asynchronous mode. The size of the recorded voice data can be large enough so that the request and response procedure may last up to 8 seconds for a recorded voice of 30 seconds. The communication with the *speech_detection_service* is achieved through a *.Post request.*

Figure.8 presents the relevant service invocation procedure from a remote robot system.

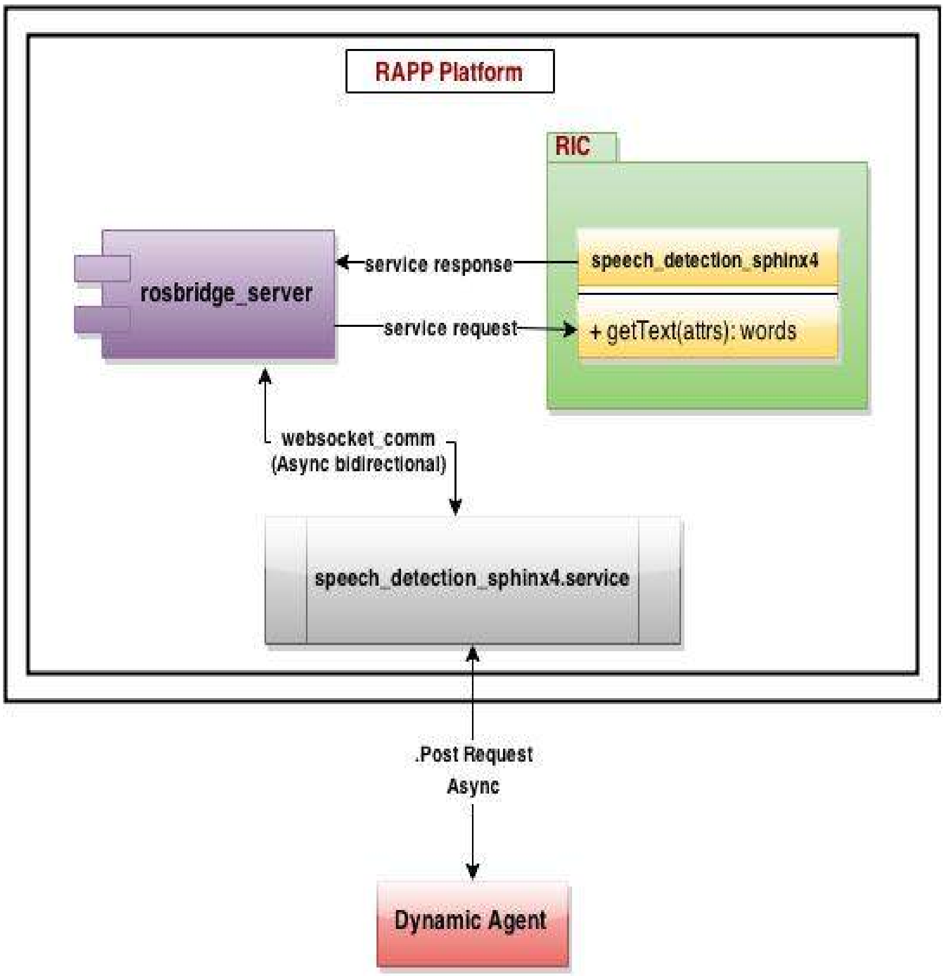

Figure 8. Speech Detection, Platform service invocation

Like already mentioned, the *speech_detection_sphinx4* service is accessible through a *.post request*. To ensure robustness, it has been implemented to function in an asynchronous mode, which means that a dynamic agent can send a request for the speech_detection_sphinx4 module and continue with other procedures while waiting for a response (non-blocking). The prototype of the service also ensures handling simultaneous requests, by defining a unique id on each request. When a request is received, the service handles the communication with the speech_detection_sphinx4 ROS Node through rosbridge. The communication between the service and rosbridge is achieved through websockets. The service is also responsible to handle the response from the ROS Node, craft a message which includes useful-only information and forward that back to dynamic agent. More specific, the response message contains the words that have been found in the voice-audio-data.

An addition to the above is that the *voice-audio-data* are transmitted by using the multipart/form-data .post type. When files are transferred, HOP web-broker is responsible to handle and store those on the RAPP Platform under a known temporary system directory.

The *input/output* parameters for the *speech_detection_sphinx4.service* are:

- *Input parameters (JSON Object)*:
    - o *fileUrl*: The location where the voice-audio-data is stored.
    - o *language*: Language to be used by the speech_detection_sphinx4 module. Currently valid language values are 'gr' for Greek and 'en' for English.
    - o *audio_source*: A value that presents the *<robot>_<encode>_<channels>* information for the audio source data. This is used for correctly denoising the audio.
    - o *words[]*: A vector that carries the words to search for.
    - o *Sentences[]*: The language model in the form of sentences.
    - o *Grammar[]*: The grammar model. When a grammar model is specified the speech recognizer tries to only identify words that belong in this set.
- *Output-parameters:*
    - o JSON object that contains a vector including the words-found.

The prototype sources for the speech_detection_sphinx4.service are located under the rapp-platform repository on github (speech_detection_sphinx4.service).

In order to perform denoising processes onto the voice-audio-sources, on a per-user profile, the relevant hop-service that handles requests for denoising profile configurations has been developed. Denoising is critical since the captured audio from NAO's microphones contains a high level of noise that makes Sphinx4 library malfunction. The denoising service has been developed in the same structure as the speech_detection_sphinx4 service.

The input/output parameters regarding the *set_denoise_profile.service* service are:

- Input parameters (JSON object):
    - o *fileUri*: The location where the voice-audio-data are stored.
    - o *audio_source*: A value that presents the *<robot>_<encode>_<channels>* information for the audio source data.
    - o *user*: User's name. Used for per-user profile denoise configurations.
- Output parameters:
    - o JSON object which carries index for success on denoise configuration.

The prototype sources for the set_denoise_profile.service are located under the rapp-platform repository on github (set_denoise_profile.service).

The procedure describing a request to the "Set Denoise Profile" module is similar to the one described above regarding the Speech Detection module and it is presented in *Figure.9.*

Figure.8 presents the relevant service invocation procedure from a remote robot system.

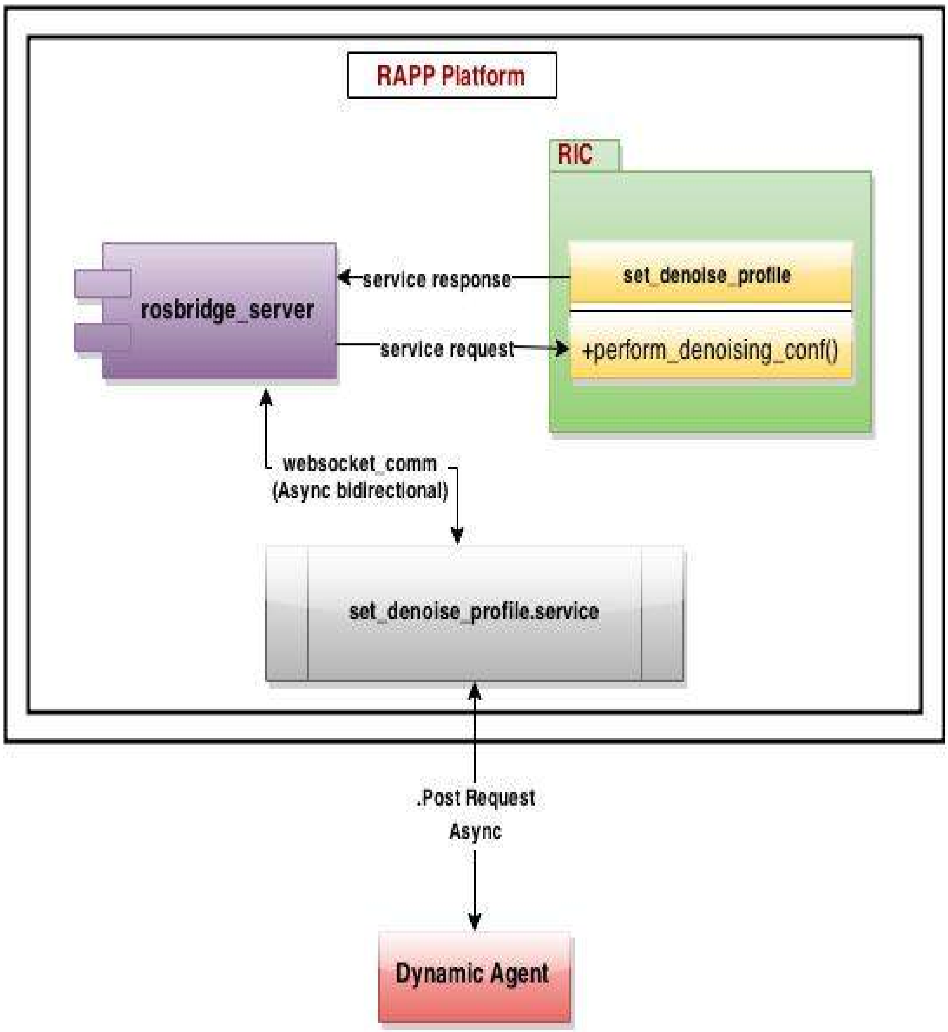

Figure 9. Denoise Profile, Platform service invocation

Technical approaches on the applications, implementations, workflows and evaluations, for each of the prototypes (Send Mail, Cognitive Game), are presented, detailed, on the subsections 2.1.1 and 2.2.2 More specifically, in *Section 2.1.1*, the *Send Mail prototype* is presented whilst *section 2.2.1* covers the prototype implementation for the *Cognitive Game prototype*.

2.1.1 Send Email via NAO Prototype Rapp

The Send Mail via NAO Rapp allows the application users to easily send an email to a desired address. Though the prototype also provides the additional functionality to the users to attach a voice-recorded audio file to the email attachments field.

In order to send emails, an open-source C++ library, *VMime,* is used. VMime is a powerful library for working with RFC-822 and MIME messages and internet messaging services like IMAP, POP and SMTP. For our application we used SMTP services to send emails on accounts hosted by gmail services (*<user>@gmail.com*).

Currently, the core-agent running on NAO, hosts the service that handles *send-mail* requests. The sent-mail service is actually implemented under a *ROS-Service*, provided by the *core-agent.*

We will address the related service as ***rapp_send_email***, for convenience.

Furthermore, the core-agent, running on NAO, also provides the following services, which are used by the SendMail RApp:

- *rapp_say*: This service is used in order to make NAO talk. It takes as input a string that will be further converted to speech.
- *rapp_record*: Used to start recording, by using NAO microphones.

Core agent is responsible to pull information regarding the client email account (*user.email_address, user.password*). This information are currently defined on the robot, in a hard-coded way from the developer. Information that presents the email receiver, are also defined statically, in the prototype. The prototype of the SendMail RApp, is executed by the core-agent when the key-word, ‘email’, gets captured.

The application workflow, for the SendMail Rapp prototype, is presented in *Figure.10*

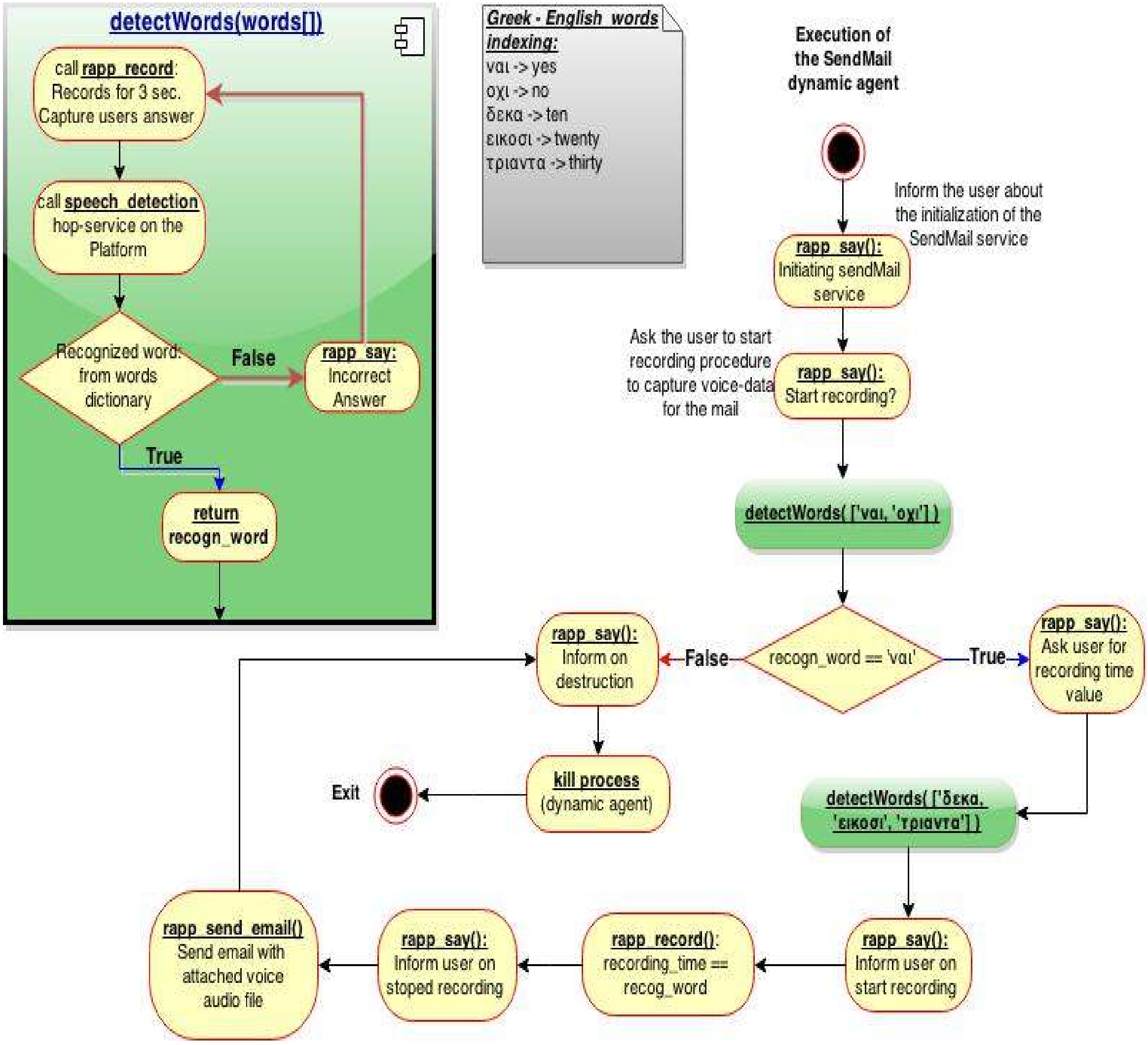

Figure 10. Send Mail Prototype – Activity Diagram

The ***detectWords(words[])*** method is used in order to record user's answers, perform speech_detection on the captured voice-audio-data through a .Post request to the speech_detection_sphinx4 hop-service, and then match the response with a vector of words given as input to the method. This procedure takes place until a valid answer from the user is captured and recognized.

To simplify the workflow presentation, we will address the aforementioned procedure as ***detectWords(words[]).***

On creation of the SendMail dynamic agent, the user is informed by NAO about the initialization of the SendMail application. This means an invocation of the ***rapp_say*** ros-service, provided by the core-agent, is performed. Next, through a second call to ***rapp_say***, NAO asks the user to confirm the initialization of the recording procedure. Valid answers from the user are Yes(Ναι) ***OR*** No(Οχι). In order to capture an answer from the user we invoke the method ***detectWords****['ναι', 'οχι'].*

If the input answer from the user is negative ('οχι'), NAO informs the user about the termination of the SendMail application and the dynamic agent is terminated.

On a positive response from the user ('ναι'), NAO asks the user to pronounce the time, in seconds, he/she wishes to record for the voice-audio-data to be attached to the email body. Valid answers are ten('*δεκα*'), twenty('*εικοσι*'), thirty('*τριαντα*') seconds. When a valid answer is recognized, NAO starts the recording procedure for time equal to the detected value. When the recording time limit is reached, NAO informs about the termination of the recording procedure. Then a ***rapp_send_email*** ROS-service invocation follows in order to attach the recorded audio-file and sent the email. NAO informs about the success of the SendMail service and then about the termination of the SendMail process. The dynamic agent is then destroyed and the application exits.

2.1.2 Cognitive Game via NAO Prototype Rapp

The core of the CognitiveGame RApp prototype uses a list of files where the stories, questions and valid answers exist. The files were locally stored on NAO robot during the evaluations. The CognitiveGame RApp prototype output is presented as a success rate of how many correct answers the user has given.

Figure.11 presents input and output parameters for the Cognitive Game component.

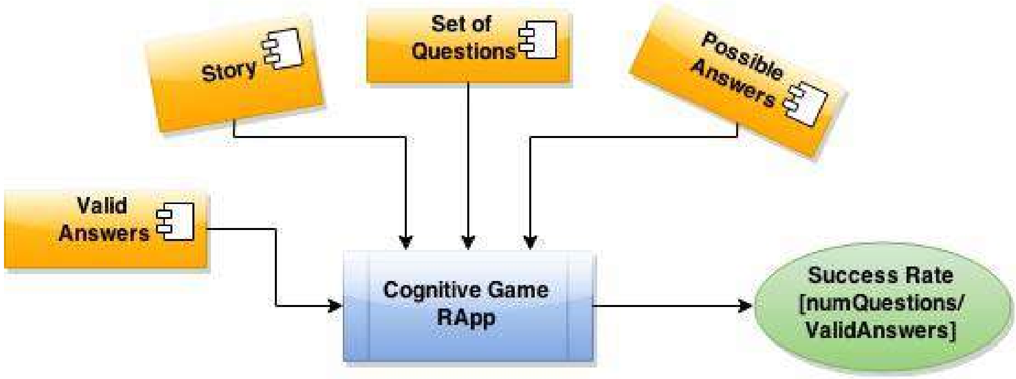

Figure 11.The Cognitive Game component – Input / Output parameters

The core-agent functionalities (ROS-Services) used in the prototype of the CognitiveGame Rapp are:

- *rapp_say*: This service is used in order to make NAO talk. It takes as input a string that will be further converted to speech.
- *rapp_record*: Used to start recording, by using NAO microphones.

The prototype of the CognitiveGame RApp, is executed by the core-agent when the key-word, '*cognitive'* is recognized.

The application workflow, for the CognitiveGame Rapp prototype, is presented in *Figure.12*

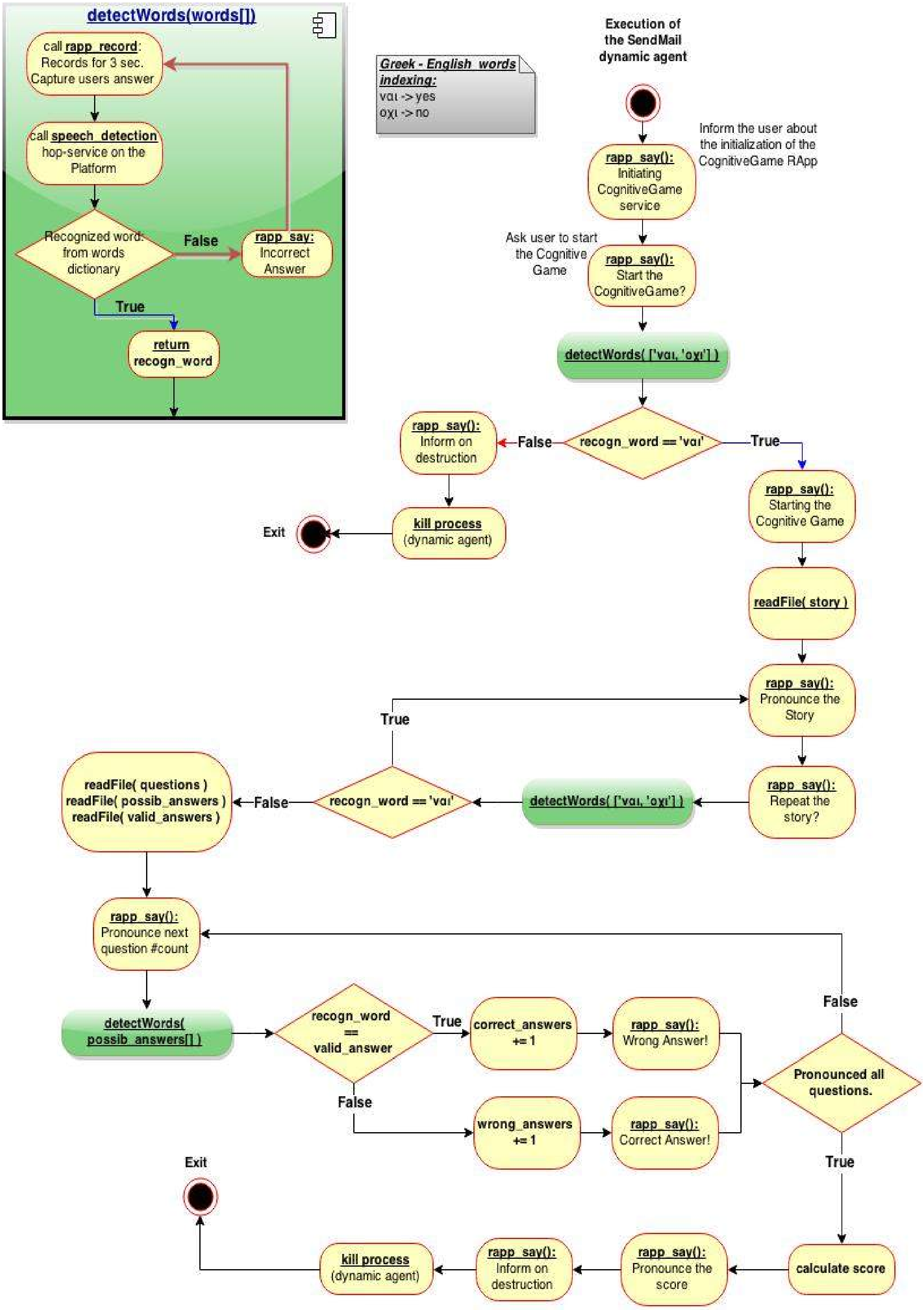

Figure 12. Cognitive Game Prototype – Activity Diagram

An implemented method, ***detectWords(words[]),*** is used in order to record user's answers and perform speech_detection on the captured voice-audio-data through a .Post request to the speech_detection_sphinx4 hop-service. Then it matches the response with a vector of words given as input. This procedure takes place until a valid answer from the user is captured and recognized.

To simplify the workflow presentation, we will address the aforementioned procedure as ***detectWords(words[]).***

On initialization, the user is informed by NAO and asked to confirm the initialization of the CognitiveGame RApp. Valid responses are only considered to be 'yes(ναι)' ***OR*** 'no(οχι)'. In order to capture a reply from the user we invoke the method *detectWords['ναι', 'οχι'].*

If the input answer from the user is negative ('οχι'), NAO informs the user about the termination of the CognitiveGame application and the dynamic agent is killed.

On positive response ('ναι'), NAO informs the user about the initialization of the CognitiveGame application and loads the necessary data. Those are:

- *story*: Contains the story in a text format.
- *story_questions*: Contains the questions on the pronounced story.
- *story_possible_answers*: Contains the possible answers to the set of questions.
- *story_answers*: Contains the valid answers to the set of questions.

NAO pronounces the story and asks the user if he/she needs to repeat it. On positive response from the user *('ναι'-'yes'*), NAO repeats the story. This procedure has been implemented in a loop format. On negative response (*'οχι'-'no'*) the relevant, questions and answers are loaded. The files containing this information are also stored locally on the NAO robot.

Next, NAO starts pronouncing the questions one at a time. On each question, the ***detectWords***() method is used in order to capture user's reply. On each answer, given by the user, it matches the user's answers to the valid story answers, which have been loaded on runtime, like already mentioned.

When all questions have been pronounced, and furthermore valid answers have been recognized, the total score is then calculated.

NAO pronounces the total score and informs the user on termination of the CognitiveGame. The dynamic agent (*CognitiveGame RApp*) is then destroyed and the application exits.

2.2 Mobility assistance and activity monitoring via ANG-med robot

2.2.1 Available hardware

Figure 13. Front and rear view of the ANG-med prototype

ANG-med is an instrumented rollator based on a commercially available walker with 4 wheels designed at INRIA. It contains:

- two servo-motors that actuate the existing brakes
- two encoders in the rear wheels
- 6 infrared unidirectional distance sensors. Four are mounted in front of the rollator, the other 2 are looking backward and are mounted on pan/tilt heads that allow to modify their direction of measurement
- one 3D accelerometer/gyrometer
- a GPS
- two infrared receivers that allow communication with a TV remote
- two 23Ah lithium-ion batteries
- a 2-lines 20 characters LCD display
- 6 leds (2 red, 2 green, 2 yellow)
- an on-off switch button
- a multi-position switch
- a general on-off switch
- a computer (fit-pc 2)

The firmware implemented in the fit-pc (written in C) is customized to manage all the available hardware and is designed to ease the use of additional sensors if needed.

2.2.2 Firmware infinite loops

The firmware implemented in ANG-med runs 3 infinite loops:

- The initiation loop: it is basically intended to be used to define which exercise will be run and beforehand to set eventually parameters that are necessary to run the exercise.
- The blocking-start loop: after having loaded an exercise this loop is intended to be used for preparing the exercise (e.g. put the subject in the right location or start the exercise if he/she is ready).
- The main loop: which is in charge of running and recording the exercise.

All these loops except the main loop may be skipped. For example if the dynamic walk is run (this exercise is automatically performed as soon as the switch button is on the ON position) the firmware will automatically exit from the initiation loop as soon as it has loaded the exercise and skip the blocking start.

2.2.3 RAPP

The exercises ARE the user empowering Robotic Applications (empowering for both the end-users and the caregivers) and are completely defined by messages that comply with the messages protocol defined in the software platform. Pre-defined exercises are preloaded only because 1) they are the most used exercise 2) they may have to be executed even without any connexion (or with a low speed connection). But as they have exactly the same structure than any other exercise new version can be downloaded at will and their behaviour may be modified on the fly. Here RAPP acts exactly as an app store: you download the application (i.e here a set of messages) whenever you can and you may then run the application off-line. With additional advantages if needed:

- The application behaviour can be completely changed provided there is connection except for the safety part of the applications
- An authorized person may follow how the application is running.

As mentioned previously ANG-med functionalities are accessible through a message passing mechanism based on rowe with an extensive catalogue (with currently over 400 messages). The walker is waiting for messages during all three infinite loops so that even pre-defined exercise behaviour may be modified at run time. This allows external developers to propose new exercises that will be made available in the RAPP store or to take direct control of the walker.

A test procedure has been defined: it allows one to test a list of messages, check if the message has been correctly executed (most of the time this verification requires a visual verification on the walker). About 1/3 of the messages have been checked in this way.

Other messages have been checked by using them directly in the exercise definition.

In parallel a clinical user manual is being written with clear instruction, a first version is already available (Annex 4).

2.2.4 Accessibility of the prototype

From the user/patient point of view the difference between ANG-med and a conventional rollator is minimal (for example the added weight is less than 3kg). Compared to our previous walkers ANG-med is more integrated i.e. the additional instrumentation is less intrusive. On the long term the hardware may be fully integrated within the walker frame so that there will be no noticeable visual difference between the instrumented and non-instrumented walker.

The additional cost is low (around 500 euros for the current prototype) but this cost may be lowered with a minimal effort.

2.2.5 Relevance and applicability of the prototypes

Inria's work before the RAPP project [11], [12] has already shown the relevance and applicability of an instrumented walker for medical monitoring. A large difference with the previous work is the possibility to use the RAPP store to download new exercises that have been developed by external partners or to use the walker message passing mechanism to develop specific exercises that will be executed in the connected mode. As standard medical exercises have been implemented and tested using this mechanism and as the messages catalogue is very large we have no doubt that other exercises can be implemented, especially for specific cases.

2.2.6 User-system interaction

The user/caregiver may interact with ANG-med through a local system (the TV remote and 2 switch buttons that are located on the walker) or through a tablet (especially for the formal/informal caregiver). INRIA has a large experience using the remote by elderly/caregiver as our previous walkers were already using this interface. Long term experiments have shown that this interface is easily adopted and is used without any difficulty [11], [12].

As for RAPP and the mobility scenario some preliminary interfaces have been developed by INRIA for the professional caregiver focused on two devices: Tablet and PC. Currently these interfaces are being evaluated at Matia to give the first feedback in order to improve them and adjust to actual needs of the professionals taking into account the already defined requirements:

- Interfaces have to be simple and easy to use.
- They have to be safe and respect privacy of users. The application will never disclose information to an unauthorized user.
- They have to provide sufficient information about the rollator status and its control
- They have to be visual and provide valuable information about important events related to the patients at a glance, colours (red, orange, green) could be used to prioritize outcomes of patients
- They have to include indicators that will show the activity of patients with the rollator and its quality, which will allow the professionals monitor progress of the patients.

Below some screen shots of the interfaces for both tablet and PC are shown:

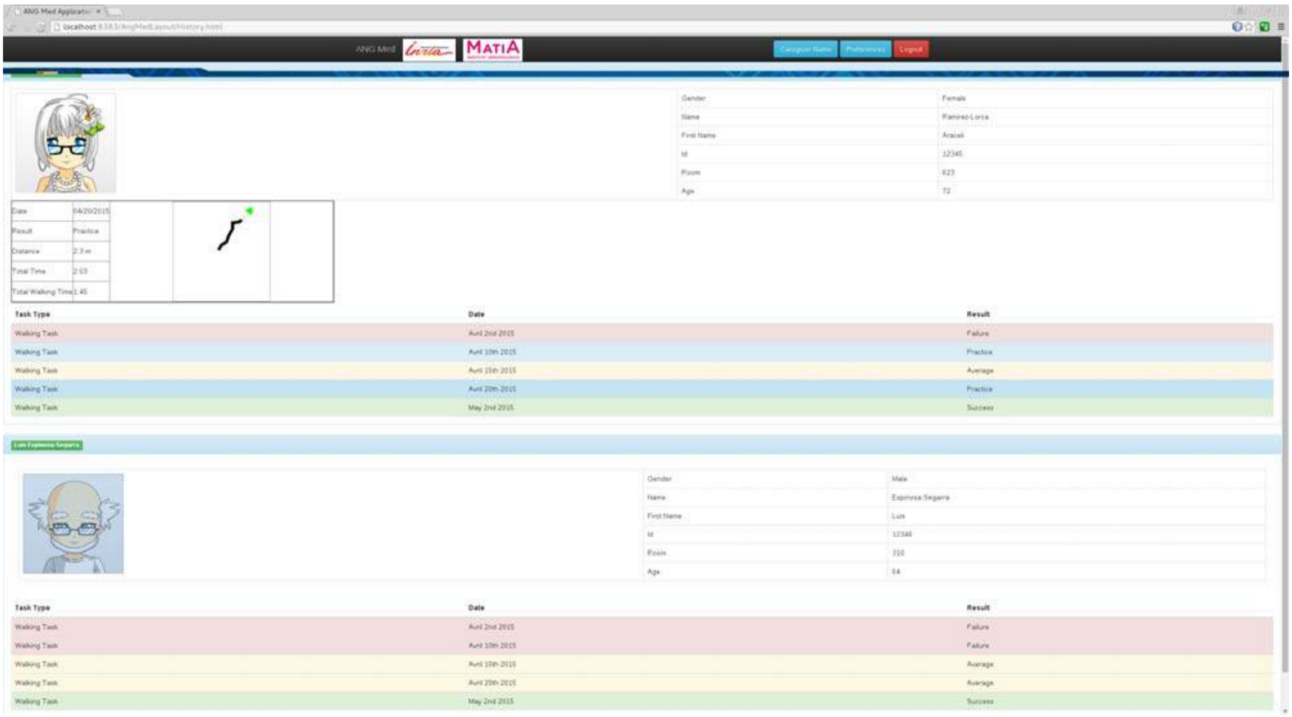

Figure 14. Patient manager interface layout for PC

Figure 14 displays history data of the users who are monitored by a given professional caregiver/clinician. Each user gets his/her own section, which can be selectively displayed or hidden. Displayed information is:

- User administrative information
- Selected task (exercise) data: Data are retrieved from the history database and displayed in a textual/graphical manner depending on the task
- Task history browser: A table of past activity, with relevant information letting the formal caregiver/clinician select a task in the history.

Figure 15 and Figure 16show different sections:

- **Rollator status** provides administrative information about the rollator
- **Rollator user** provides the user profile of the current rollator user and links to user past activity)
- **Rollator control** lets the formal caregiver specify the current task (exercise), view associated data while the task is performing and after completion, view battery and rollator brakes status or turn off/on the brakes. The professional can control the exercise performance on real time when the rollator is connected by the start/stop/pause buttons, which are common to all tasks.

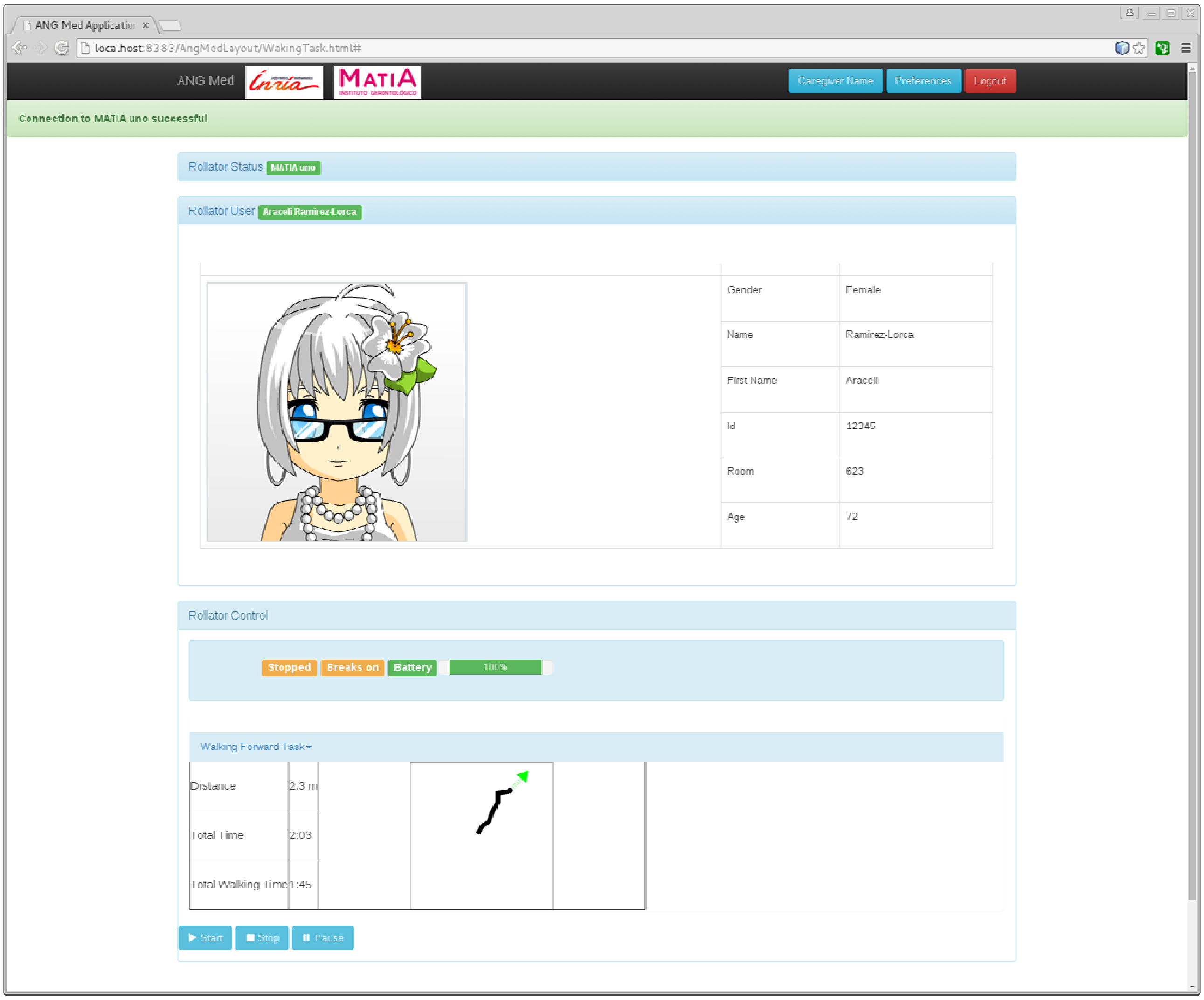

Figure 15. User information displayed on PC when the rollator is WI-FI connected and ready to perform an exercise

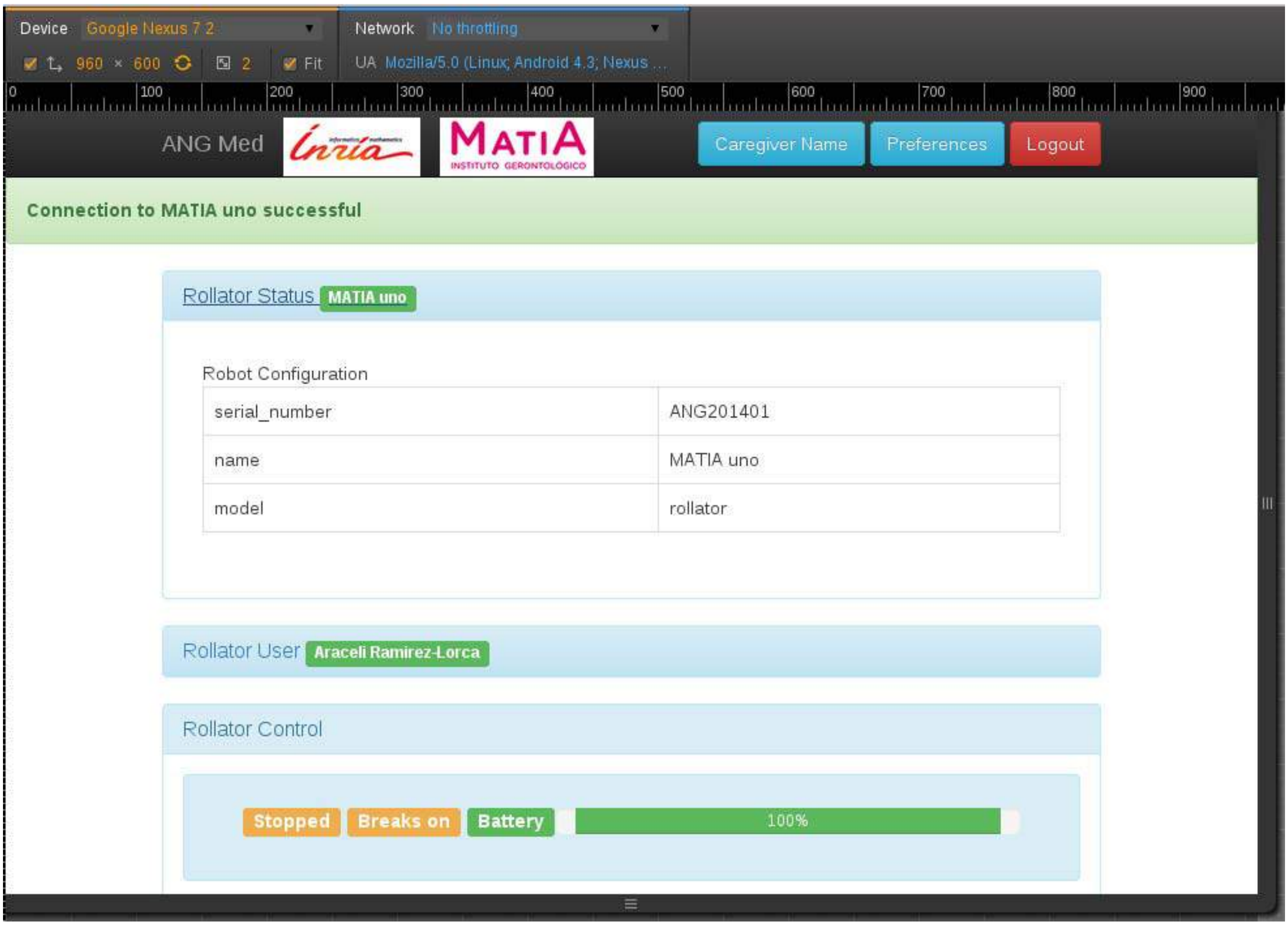

Figure 16. Rollator status displayed on Tablet

3. Evaluation methodology and standards

3.1 Technology illiterate people

3.1.1 Methodology

For the needs of the pilot testing, the focus group of the technology illiterate seniors was used (N=6). Both pilot tests took place at the leisure room of the Seniors Centre where all the meetings with our users took place up to now. Focus groups in an accepting and safe environment can reveal a wealth of information allowing users to describe their experience in their own words and share their feelings. We have chosen to use this focus group as they are those seniors attending continuously and actively the "technology classes" organized by ORMYLIA at the Seniors' Center of the city of New Moudania (Chalkidiki, Greece) and both the venue and the trainers were familiar to them ensuring that they would feel safe and comfortable to participate. They had already met NAO before which made them feel secure using the robot and share their experience.

During the trials, the robot (NAO) was brought to the center in one of the regular group meetings and it was included in the daily schedule. The portable computer lab, which has been organized from the beginning of the technology classes, was set up as usual and seniors could exercise while waiting to take part at the RApp pilot tests. In this way, they didn't feel bored or used for experimental reasons. In a spot at the same room, NAO was prepared and met seniors one by one to test the Send Mail and the Cognitive Games scenarios.

All the participants (N=6) tested NAO for the Send Mail scenario first and subsequently for the Cognitive Game scenario. At the end of the testing, a personal interview followed where the participants were asked about their experience with NAO and their evaluation of the applications and the robot performance. A short questionnaire (Annex 2) with open ended questions was used to structure the interview. The participants were asked to describe:

1. The general performance of NAO in a scale from 1 to 5 where 1 stood "not satisfied at all" and 5 for "very satisfied".
2. What might have been difficult for them.
3. What they would like to change at the procedure.
4. If they would rather sent emails through personal computers or through the robot.
5. If they would like to exercise their memory with cognitive games like the one presented to them during the tests.
6. If they would rather exercise with cognitive games through personal computers or through the robot.
7. If they would like to comment something more.

There has to be noticed that in the long term, all the produced RApps will be tested in a larger scale where groups of MCI seniors and caregivers will take part. Qualitative methods analysis will be preferred using interviews and observation as they serve better the needs of this research and the specific nature and the needs of the users. However, quantitative approach will also be followed in some cases as standardized tools are used to test the cognitive and psychological status of the MCI users and standardized questionnaires will explore their interaction with robots, like:

- The Negative Attitude toward Robots Scale (NARS) by Nomura (2006) which measures negative attitudes toward robots in general [13].
- The Robot Anxiety Scale (RAS) by Nomura (2006) which measures anxiety toward the robot in front of respondents [14].
- The Godspeed Questionnaire by Bartneck (2009) which measures the anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety of robots [15].

The results will be evaluated to test the usability and acceptability of the RApps.

3.1.1.1 Ethics

The participants were informed about the test pilot scope and procedure and voluntarily offered to take part. A consent form (Annex 3) was distributed and signed by them at the beginning of the testing procedure.

3.2 Mobility assistance and activity monitoring

Currently there is no standard for robotized mobility assistance, which has not been commercially deployed yet.

For monitoring already existing medical tests has been used in order to provide the same indicators that have been medically validated. Additional indicators provided have been medically checked as relevant but will become standards only when sufficient statistical data have been obtained (this may take years) and devices that make them measurable are commercially available.

ANG-med hardware and firmware have been tested at INRIA in the Hephaistos test facility that includes a rehabilitation area and a realistic flat (with a kitchen, bedroom, toilets and relaxation area) by using 5 subjects with age between 32 and 58. Only pre-defined exercises were tested. The exercises have been realized in a simulated fully connected mode where the RAPP application is replaced by a test control station (using the rowe communication protocol to discuss with the firmware, like the final prototype will do).

Also to complement the long term trials that will be performed by MATIA other similar walkers will be deployed locally at Nice hospital and in a rehabilitation centre. As the HEPHAISTOS research team of INRIA includes a specialist of high-tech devices evaluations we are currently working on an evaluation methodology (through questionnaires and other means) for both the subjects and the caregivers. These means will be tested in the preliminary deployment of ANG-med and will then be provided to MATIA.

Tools used at INRIA to test the ANG-med prototype and the measurements that can be collected by the sensors to give indicators on the activity performed:

- **10m walking**: Based on the Timed 10 meter Walking Test (10mWT) by Bohannon [9], which is a performance measure used to assess walking speed in metres per second over a short distance. Here the subject has to walk 10m in a maximal straight way using the rollator. The indicators are the distance travelled, the time, the maximal speed, the maximum of the lateral deviation. Additional indicators such as number of steps, pressure on the handle are obtained with the post-processing.
- **Timed Up & Go (TUG):** According to the procedure time needed to rise from a chair, walk 3 meters, turn and walk back and sit down is measured [10]. The test is performed twice and the mean time (seconds) of the two trials is used as outcome. Participants are instructed to use walking aids support if used regularly. Repeated tests aim to obtain fast speed while preserving safety, irrespective of using walking aids or not. TUG is well validated and has been used in several studies on hip-fracture patients to predict falls, to assess functional mobility and to assess effect on home-based therapy.
- **Inverted L exercise:** this exercise is similar to the 10m walking exercise except that the trajectory has the shape of an inverted L, i.e. it includes a straight line trajectory of 5m, a left/right turn, a straight line trajectory of 5m, a turn around, then a straight line trajectory of 5m, a right/left turn and a straight line trajectory of 5m to come back to the starting point. The indicators are the same than for the 10m walking exercise except that post-processing will allow obtaining pertinent medical data for the manoeuvre part of the trajectory, especially the turn-around.
- **Maze:** the subject has to move in a given environment with multiple obstacles from a starting point to a goal point while avoiding the obstacles. The indicators for this exercise are the time, the travelled distance and the minimal distance between the walker and the obstacles.

4. Early results

4.1 Technology illiterate people

NAO was tested at the leisure room of the Seniors Centre at New Moudania. The focus group of Technology Illiterate seniors participated at the pilots (N=6) and tested both initial scenarios of Send email and Cognitive Games. The participants were between 63 and 78 years old. Unfortunately, NAO was not able to use Greek language. Aldebaran

(Softbank Group) informed us that Greek language will be available at the next update version of NAO which is still expected. Indeed, NAO didn't manage to speak Greek but he was able to understand Greek words.

Preceding the testing of the scenarios with real users, lab tests were performed to test the sustainability and function of NAO.

4.1.1 Human-robot interaction

The user group of Technology Illiterate seniors was already familiar with NAO as the robot was presented to them in a previous session. Still, their familiarity with the robot was significantly marked due to their differentiated and more positive approach towards NAO. When NAO was presented to the group for the first time, their reaction was restrained and indifferent towards the robot. They were not sure of what to expect and they felt uncomfortable and alienated. During their second contact experience with the robot they were comfortable of approaching it and willing to use it. The actual scenarios were interesting to them and their usefulness was clear.

They all used the Send email RApp to send an email with their message recorded and attached as a sound file and they enjoyed receiving the same mail and listen to it. They were enthusiastic to test the Cognitive Game RApp and two of them asked to repeat the game and improve the score.

The interviews revealed that they approved the procedure in both RApps and find them interesting, useful and easy to use. They were disheartened with the lack of Greek language and they all mentioned it. They were also disappointed with the hearing of NAO as they usually had to repeat their orders for NAO to listen and perform accordingly.

Concerning the usability of RApps, four out of the six users (4 in 6) commented that they would rather use RApps and robots while one (1 in 6) stated that would use both robots and computers for sending emails and play cognitive games and one (1 in 6) that he would rather use his personal computer only as he feels that he can have the control of his actions only through that. It should be acknowledged that this user faced more difficulties with NAO during the tests as his voice is low and he had to repeat his orders again and again.

Note: As the pilot tests took place at the leisure room of the seniors' center, we made an open invitation to seniors who were present reading their newspaper or playing cards to try the RApps and "play" with the cognitive game. They were reluctant to join us and hesitated to interact with the robot. Only one senior (84 years old) approached and used the RApp with NAO. He had a technical professional background which facilitated his interaction with the robot. As he commented afterwards, he found it easy to use and amusing.

4.1.2 Quality of Experience

4.1.2.1 Send email

The behavior of the Prototype of the Send Email via NAO RApp has been classed to be impeccable.

Furthermore, the bidirectional communication from/to the RAPP Platform (Cloud) has been tested with success.

The Speech Detection module developed under RIC, which has been used in order to recognize words as responses from the users, succeeded on recognizing Greek words on a high rate, under low-noise or none-noise environments.

Future Work:

- Allow users to attach images on the email body.

- Perform further or dynamic denoising on the voice-audio-file. This assumes that the relevant RAPP Platform service will be provided to the developers in order to send the file (on the RAPP Platform) for audio denoising purposes.
- Recording time for the audio-file to be attached onto the email body should not be hardcoded. That means the dynamic agent should handle stop recording procedure when no voice for a predefined time value, is present.
- Install the rapp_send_email service onto the RAPP Platform.
- Allow users to select the receiver of the email via a list of predefined users/email_accounts.

4.1.2.2 Cognitive Games

Failures on recognizing words under a noisy environment have been observed. In order to better capture the responses from the users, the denoise profile configuration should be invoked dynamically. It has been observed that under environments where the background noise has a dynamic behaviour, the denoise profile configuration does not work as expected.

Future Work:

- Capture responses from the users, dynamically.
- Perform denoising under dynamic noisy environments.
- Create more stories.
- Allow users to select the desired story from a list of predefined stories.

4.2 People with MCI

As it was mentioned above (1.2.1, Important Note), the Cognitive Game scenario was tested with the group of the technology illiterate seniors. As NAO is still not eligible to speak in Greek, pilot tests could not be performed at the Greek Association of Alzheimer Disease and Relative Disorders. We should translate in parallel with the execution of the game and this could create confusion and discomfort to the users. As the specific users (both patients and their therapists or caregivers) are a very sensitive group, we decided to postpone testing until the next version update of NAO and the availability of Greek language.

A meeting with the professionals of the Greek Association of Alzheimer Disease and Relative Disorders is planned to involve them in the testing planning and organization.

4.3 Mobility assistance and activity monitoring

ANG-med components have been tested separately in three blocks:

- the hardware and firmware.
- the RApp application
- the mock-up of the web user interface to monitor and control ANG-med operations.

Hardware and firmware tests permit to validate the ability to implement the exercises defined by MATIA, that is operate ANG-med actuators, measure data and synthetize relevant indicators.

Tests on the RApp application demonstrate the viability of the distributed software architecture specific to the RAPP project.

The parallel development of the web user interfaces for caregivers and patients enables users to provide feedback on the application before it is actually fully integrated.

The integration of the RApp application with the firmware/hardware components is scheduled to happen at the end of June 2015.

4.3.1 Autonomy

Preliminary experiments have shown that the two 23Ah lithium-ion batteries will provide an autonomy that will be at least 24 full hours (a test without the low-consumption on board computer have been run for three full days and the battery level was still at 50%).

Energy saving mechanism has been implemented so that this number will probably be a lower bound. In any case the battery may be fully charged in less than 2 hours so energy problems are not expected.

4.3.2 Test of position determination

It was unclear if the determination of the user position with respect to the walker (too far, too close, correct) by using the rear looking distance sensors could be done. Extensive testing has shown that this was indeed the case, not only in the static way (the user is not moving) but also during dynamic exercise (e.g. the user is walking). A position indicator has been defined that ranges between 0 and 100 (0= too close, 100=too far, correct position= between 50 and 70).

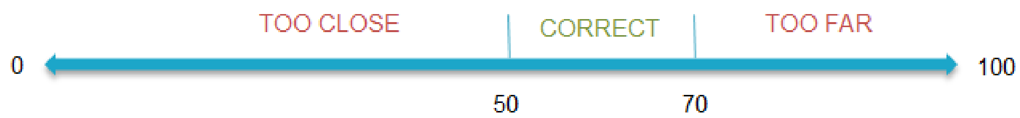

Figure 17. Position indicator ranging from 0 to 100

Clearly the quality of the position determination will rely on the orientation of the rear sensors. A standard orientation has been defined and has allowed performing a good position estimation of the 5 test participants. However we have anticipated possible problem with the standard orientation for user presenting a specific morphology. A calibration procedure has been defined, implemented and tested so that an optimal orientation may be defined in specific cases. As soon as the optimal orientation has been determined it is stored in the user's profile so that if a user has a specific orientation setting, then the rear sensor orientation will be set to the specific setting when the subject is identified (by his RFID tag, or by the caregiver.

4.3.3 Test of handle pressures

Pressure exerted by the user on the handles of the walker is an interesting medical indicator as it provides an assessment of the support help required by the user. However we were not willing to include 6 degrees of freedom force sensors in the handle as they are expensive, rather bulky (they need to be able to support up to the full weight of the user) and relatively fragile. Furthermore, given the necessary measurement range (from almost 0 Newton when the user is just pushing the walker up to several hundred Newton when he/she is fully leaning on the handle) the accuracy of the measurement is relatively low.

Inria's previous work on other walkers [11], [12] have shown that using the 3D accelerometer for measuring the tilt of the walker may be sufficient to have a correct measurement of the pressure on the handle. Indeed the wheels of the walker are relatively elastic so that when a sufficient pressure is exerted on the handle the tilt angles of the walker will change by a small amount that still can be measured. However, the amount of tilt change will depend upon the weight and morphology of the user. Hence a calibration procedure has to be used for each user. As for the position calibration this procedure has to be performed only once as it will be registered in the user profile.

4.3.4 Exercise tests

We have performed about 100 **"dynamic walk" exercises** in our environment that has allowed to fine tune this exercise. Although the post-processing of the data is not completed we believe that this exercise may be deployed in its current state in a realistic hospital or rehabilitation centre. The summer deployment will allow us to fine tune this exercise for elderly people and for getting data for the post-processing phase. Compared to our previous works with walkers a big difference is the position estimation assessment.

In this trial the subject has to move twice along the same trajectory which is basically an inverted L, make a turn-around and come back to the same starting point. On one trajectory the person has to enter in a room. The total travelled distance is 100m.

Below an example of the gathered results in a "dynamic walk" is shown:

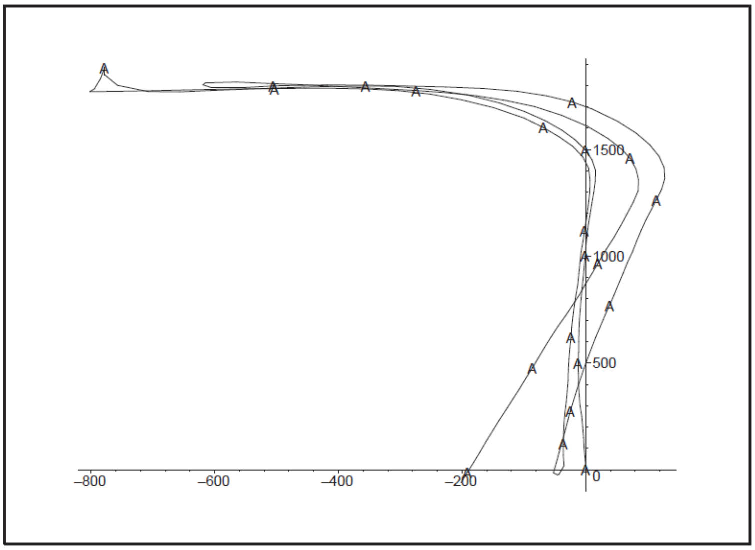

Figure 18. Typical Dynamic walk exercise (inverted L)

The provided indicators at the end of the exercise were:

- Maximum speed: max_speed 161.609733 cm/s
- Mean Subject position: mean_subject_position 82.848081. The subject was somehow too close to the walker (range from 0 to 100, being 0 too far and 100 too close)

- Handles pressure: mean_subject_handles_pressure 26.502562 75.402424 21.785351
  - Fisrt number is the forward/backward pressure on the handle between 0 (no weight on the handle) and 100 (patient's full weight on the handles). Here the subject is slightly supported by the walker (26.502562)
  - The 2nd and 3rd numbers are the mean pressures on the left/right handles. Here the subject is leaning more on the left handle, which is normal as he is left-handed (75.402424 / 21.785351)

We have also performed about 50 **TUG exercises** and 50 **10m walking exercises** with the walker. We are quite familiar with these exercises as we have already performed them with over 50 subjects in previous experiments. These preliminary experiments have shown that the added communication part does not introduce significant differences in the data that are collected during the exercises.

We have also performed about 100 **hip extension exercises** that have been designed especially according to the requirement of MATIA. The figure presents below shows a record of the measurement of the rear left distance sensor. It may be seen that the recorded measurement is smooth enough to detect how many exercise have been performed and will provide interesting information on how this exercise is performed.

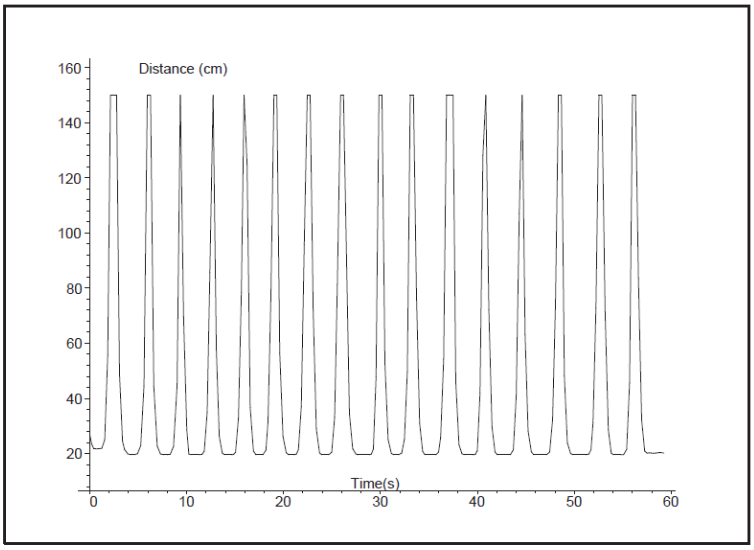

Figure 19. Typical distance signal for hip extension exercise

A lower number of **hip flexion exercises** have been performed but we are confident that this exercise may be fully implemented although with possibly a higher rate of failure than the hip extension as the change in distance in this exercise is lower than for the hip extension.

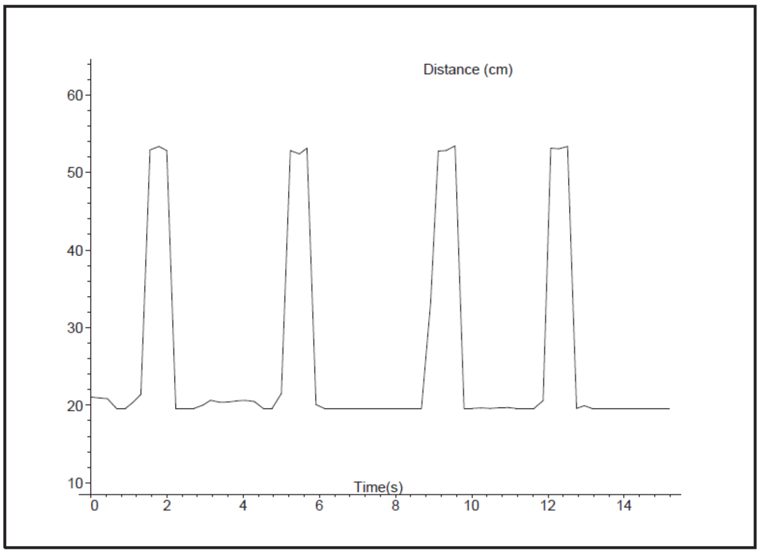

Figure 20. Typical distance signal for hip flexion exercise

Hip abduction has been the less tested among the hip exercise with a number of test of about 20 experiments. Technically the hip abduction exercise is the most complex as it involves a motion that is lateral to the main axis of the walker while this is the direction in which the walker may provide the less information. The actual implementation of this exercise has shown that it is possible to count the number of repetitions but not determining the amplitude of the abduction. Indeed to measure this amplitude it is not sufficient to measure the distance between the leg and the walker along a fixed orientation but it is required that the distance sensor direction of measurement to follow the leg motion. Although the servos that are used to orient the measuring head are fast it is unclear if they can be controlled in a sufficiently accurate way and in real time to follow the leg. However, if the abduction amplitude is larger than a fixed threshold it can be measured somehow measuring the time it takes for the subject to come back to this threshold, assuming a constant speed for this exercise.

Below an example of the indicators that can be measured for hip abduction exercise:

- Number of repetitions performed: number of local_exercices 4. Four abductions have been performed.
- Mean duration of the abductions: distance_signal mean_duration 5.849145
- Minimal duration of the abductions: distance_signal min_duration 3.538522
- Maximal duration of the abductions: distance_signal max_duration 12.540440
- The mean, min, max time for getting the leg down after performing the abduction: distance_signal stat_down_duration 3.627642 2.618659 9.988194

As for the **plantar flexion exercise** there were some doubts whether this exercise can be monitored with the distance sensor. Although it is trickier than extension, flexion or abduction, measurements can be done provided that the subject is at the right distance (the caregiver can determine it before starting the exercise as the 2 yellow led of the interface should be lighted).

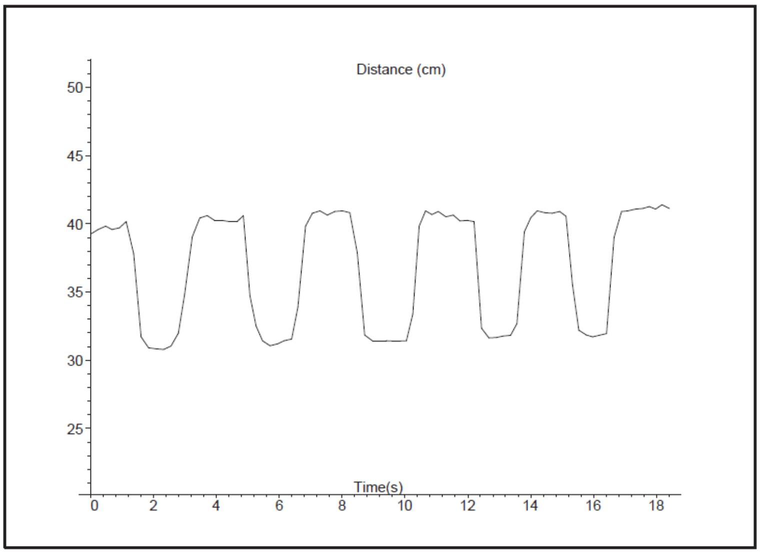

Figure 21. Typical distance signal for plantar flexion exercise

A total of 100 tests have been performed for the **10m meter walking, TUG and inverted L exercises**. We already know that these tests are relevant for the medical community and the tests were performed only to check if the introduction of the message passing mechanism does not introduce delays in the real-time processing that may significantly modify the value of the indicators. Half of the tests have been performed in the stand-alone mode without using the message passing mechanism while in the other half the mechanism was fully used. No significant differences were found between the exercises beside normal variation that may be attributed to uncertainties in the measurement and normal variation of the walking pattern of a given person.

Ten experiments have been performed for the **maze exercises** and have shown that the exercise was working correctly. It remains to show that this exercise provides significant data for the medical community.

4.3.5 Tests of the RAPP application logic

The above tests have enabled to validate the operation of the hardware and firmware and also to confirm that relevant data could be obtained from the firmware processors in selected meaningful use cases.

Within the RAPP project, an additional layer of software runs on top of the firmware, providing dynamic behaviours to ANG-med, distributed operations with the RAPP platform components, and web front end for client applications (PC / tablet).

The application logic is the software that runs embedded on the robot (above the firmware) and on the RAPP platform. A number of technical tests have been performed to validate critical functions of the application:

- Communication with the firmware. A firmware simulator has been developed from the firmware external specifications, and tests have been performed to validate Rowe message passing between the embedded RApp and the simulated firmware. These tests will be completed during the integration phase against the actual firmware.
- Installation of exercises. This task corresponds to the configuration of ANG-med firmware to perform specific scheduled measurements.

- Start/Stop and exercise. This task corresponds to the actual recording of data sent by the firmware to the application layer.
- Replacement of an exercise. This task aims to validate the dynamic replacement of an ANG-med exercise by another one.
- Patient management. This task consists in modelling the patient record and activity data, and validates that these data can be stored to and retrieved from the RAPP platform database.
- Caregiver authentication. This task consists in managing caregiver authentication to the whole system (a single authentication is propagated across the platform and ANG-med robot using session tokens). All external requests pass through the authentication filter.

4.3.6 Tests of the RAPP application user interface

The ANG-med RAPP includes a web user interface component to let caregivers and patients interact with ANG-med and data repositories. This component is directly visible to users and thus requires that users, MATIA, and Inria collaborate in its definition.

It has been determined that caregivers will preferably use a PC whereas patients are more likely to use tablets, which can conveniently be brought to the user instead of requiring the user to move to the PC workstation.

In addition, caregivers and patients expect to use different user interfaces: the caregiver UI provides a full control on the ANG-med configuration and operation and on patient records, whereas the patient user interface presents simplified progress reports and objectives, always in a positive way, to support the patient efforts.

From the above requirements, mock-ups of the UI have been built around essential concepts of the application:

- PC / tablet option for everyone.
- Enforce user authentication
- Provide a seamless integration of platform and robot components (from a web client perspective, there is a unique application. The user does not know whether he is connected to the robot or to the RAPP platform running remote services).
- Provide a generic layout for exercise control/monitoring that is dynamically adapted depending on the actual exercise (a plugin UI is defined for each exercise).
- Provide UI components for exercises (plugins) matching evaluation criteria defined by MATIA and ANG-med capabilities.

Each iteration of mock-up is developed by the Inria software team and discussed with MATIA and the robotic team. The iterative process will continue on the real application UI until it is validated by caregivers and patients (during the experimentation phase).

Several UI specifications have already been improved thanks to the evaluation of the UI mock-up:

- Welcome caregiver screen. MATIA has demanded that the records from patients who need special attention be put on top of the list.
- Patient record. MATIA has suggested that caregivers may input text notes.
- The number of colours used in the application should be limited (no more than three different colours should be used).
- Roboticians have suggested extending the user interface to allow fine control of the brakes and exercise operation (cancel button).

Conclusions

Since we are still at the early stages of RApps development, implementation and evaluation, conclusions are also premature to be extracted. What is obvious by the experience gained up to now is that seniors learn with enthusiasm and consistence. Their reservation on using technology and robots withdraws as soon as they are getting in touch with them. The interaction with robots reveals the usability and acceptability of the robots as well as the needs of the seniors that still have to be addressed. All the above define the future actions of RAPP partners in order to offer meaningful and useful applications.

These already implemented RApps and the ones that will follow will be further evaluated by researchers, professionals and senior users to make sure that the final prototypes will be safely launched for the large scale pilots.

Annexes

ANNEX 1

Pilot Cognitive Game- Text

Every Saturday Mary and her family go to the beach. Mary loves the beach! They live far from the beach, but once a week the family gets into the car and Mary's father drives for three hours until they arrive. Mary's parents love the beach. Mary and her brother Alex love the beach.

But it is a problem to go to the beach every week. Mary's father gets tired from driving so many hours. The rest of the family gets tired from sitting in the car for so many hours.

Mary and her brother tried to go the swimming pool, but it is not the same thing. They are very sad because they can't go to the beach as often as they want.

Then one day, Mary's brother had an idea. "We need to live near the beach" he said. "We should move to a house near the beach". Mary is very happy with this idea! Mary's mother is also happy with this idea. But Mary's father is not happy with the idea as he will have to drive every day for three hours to go to his work….

Q&As:

1. Mary's family goes to the beach every Sunday (Yes or **No**)
2. Mary is going to the beach with her dog (Yes or **No**)
3. Mary loves the beach (**Yes** or No)
4. Mary's father drives to the beach for one hour (Yes or **No**)
5. Mary's parents hate the beach (Yes or **No**)
6. Mary has a brother, Alex, who loves the beach (**Yes** or No)
7. Mary's family gets tired from the trip to the beach (**Yes** or No)
8. Mary and her brother tried the swimming pool but prefer the beach (**Yes** or No)
9. Mary had an idea! Live in a house near the beach! (Yes or **No**)

10. All the family is happy with this idea (Yes or **No**)

ANNEX 2

Questionnaire

Δραστηριότητες του NAO

Activities related to NAO

Using the scale provided below, please indicate to what extent each of the following items best corresponds to the reasons why you perform the following activity.

Καθόλου	Λίγο	Μέτρια	Καλή	Πολύ καλή
Not at all	a little	moderately	good	very good
1	2	3	4	5

1. Σε γενικές γραμμές, πόσο ικανοποιητική ήταν για εσάς η απόδοση του ρομπότ (NAO)?

In general, how satisfactory was for you the performance of the robot (NAO)?

1 2 3 4 5

2. Σας δυσκόλεψε κάτι και τι?

What might have been difficult for you?

……
……

3. Τι θα θέλατε να αλλάξει στην διαδικασία?

What would you like to change at the procedure?

……
……

4. Θα προτιμούσατε να στείλετε τα μηνύματα σας (mails) μέσω του υπολογιστή ή μέσω του ρομπότ?

Would you rather sent your emails through your personal computer or through the robot?

………
………

5. Θα σας άρεσε να ασκείτε τη μνήμη σας με γνωστικά παιχνίδια όπως αυτό που παρακολουθήσατε?

How would you like it if you could train your memory with cognitive games like the one presented to you?

………
………

6. Θα προτιμούσατε να εξασκηθείτε με γνωστικά παιχνίδια μέσω του υπολογιστή ή μέσω του ρομπότ?

Would you rather exercise with cognitive games through your personal computer or through the robot?

………
………

7. Έχετε κάποιο άλλο σχόλιο να προσθέσετε?

Would you like to comment something more?

………
………

ANNEX 3

ΕΝΤΥΠΟ ΣΥΓΚΑΤΑΘΕΣΗΣ

Ερευνητικό Πρόγραμμα: **RAPP _ Εφαρμογές Ρομποτικής για ηλικιωμένους**

(FP7-ICT-2013-10)

Ερευνητικό κέντρο: Ίδρυμα Ορμύλια

Ο σκοπός της έρευνας έχει πλήρως αναλυθεί και εξηγηθεί σε μένα. Είχα την ευκαιρία να ρωτήσω τις απορίες μου και να συζητήσω τη συμμετοχή μου. Όλες μου οι ερωτήσεις απαντήθηκαν ικανοποιητικά.

Συμφωνώ να συμμετέχω στο ερευνητικό πρόγραμμα και αντιλαμβάνομαι ότι έχω το δικαίωμα να μην απαντήσω όποια ερώτηση δεν επιθυμώ ή να αποσυρθώ από την έρευνα ολοκληρωτικά. Μου έχουν δοθεί διαβεβαιώσεις ότι δεν θα υπάρχει καμία επίπτωση αν δεν δεχθώ να απαντήσω στις ερωτήσεις ή αν αποσυρθώ από την έρευνα ολοκληρωτικά και ότι κανένας άλλος εκτός από την ερευνητική ομάδα δεν θα έχει πρόσβαση στις πληροφορίες αυτές.

Δίνω την έγκριση μου ώστε τα αποτελέσματα αυτής της έρευνας να χρησιμοποιηθούν στην τελική έκθεση και στις παρουσιάσεις και/ή δημοσιεύσεις που θα ακολουθήσουν με τον όρο της προστασίας της εμπιστευτικότητας και του απορρήτου των προσωπικών μου στοιχείων.

Υπογραφή:

Όνομα:

Ημερομηνία:

Consent form (the original was distributed in Greek language. This is a precise translation)

PARTICIPATION CONSENT FORM

Research Project: **RAPP** _ Robotic Applications for Delivering Smart User Empowering Applications ***(FP7-ICT-2013-10)***

Researcher: ORMYLIA FOUNDATION

The researcher has fully explained this study to me. I have had the opportunity to ask any questions and discuss my participation. Any questions have been answered to my satisfaction.

I agree to participate in this research project, and I understand that I am free to refrain from answering any question I do not wish to answer, or to withdraw from the study completely. I have been assured that I will not be penalized in any way for withholding information or withdrawing from the study, and that nobody other than the researcher and her immediate research group will have access to the information.

I give my permission for results from the research to be used in the final report and in subsequent publication and/or presentation of results providing my identity is kept confidential.

Signature:

Name:

Date:

ANNEX 4

Large Clinical user manual of ANG-med
Version 1, May 2015
J-P. Merlet

1 Introduction

ANG-med is an instrumented rollator based on a commercially available walker with 4 wheels designed at INRIA. It has

- two servo-motors that actuate the existing brakes
- two encoder in the rear wheels
- 6 infrared unidirectionnal distance sensor. Four are mounted in front of the rollator, 2 are looking backward and are mounted on pan/tilt heads that allows to modify their direction of measurement
- one 3D accelerometer/gyrometer
- a GPS
- two infrared receivers that allow communication with a TV remote
- two 23Ah lithium-ion batteries
- a 2-lines 20 characters LCD display
- 6 leds (2 red, 2 green, 2 yellow)
- a on-of switch button that will be called the *main switch*
- a multi-position switch
- a general on-off switch
- a computer (fit-pc 2)

2 Exercises

ANG-med is basically designed to execute *exercises* that may be defined as a clinical act whose purpose is to monitor the behavior of a subject and provide an objective assessment of this behavior. This monitoring may be *passive* (the walker just record and report the behavior) or *active* (the walker is part of a rehabilitation process and report data about this process). The report provided by ANG-med are basically of two types:

- *synthetic indicators*: they summarize with a few numbers the overall behavior of the subject after an exercise is completed or during the execution of the exercise
- *full record*: ANG-med may produce record files (that may be quite huge) during the execution of an exercise. These records are intended to be processed by specific software to provide a more detailed analysis of the exercise than the one provided by the indicators

ANG-med is basically designed to work under two modes:

- *stand-alone*: this mode does not require any internet connection. In this mode ANG-med will receive orders from the available interface that will be described later on

- *connected*: in this mode ANG-med has to be connected to internet through a wifi connection. In this mode it may receive orders from a tablet or a PC that will be called the *control* in this document

The stand-alone mode is the simplest one: it allows to use almost immediately ANG-med as the setup time is reduced to a minimum. The drawbacks of this mode are that ANG-med is able to execute only a set of predefined exercises (whose list is however quite extensive) and that in this mode it is possible only to report synthetic indicators and at a relatively slow speed.

In the connected mode the overall behavior of ANG-med may be controlled from the tablet. This allows one, for example, to design or download a specific exercise, to run a predefined exercise but to modify its behavior according to the measurements provided by the sensors from ANG-med and to download efficiently the indicators ... The weaknesses of this mode is that a wifi failure may prohibit the execution of the exercise (although the firmware in ANG-med has be designed to always try to preserve the safety of the subject) and that the execution of an exercise through the wifi connection will be less efficient from a real time viewpoint because of the communication delays.

Note that the two modes can coexist. For example ANG-med may be started in a connected mode (e.g. to download a specific exercise) then be run in the stand alone mode and again be switched to a connected mode after the completion of a serie of exercises in order to get efficiently the exercise reports (e.g. at the end of the day).

3 Interface and hardware

ANG-med has several interface means. In the stand-alone mode the interface elements are on the *LCD box* and through the remote.

3.1 LCD box

The LCD box is located in the box close to the seat of the walker. It include the LCD display, the main switch, the leds and the multi-position switch (figure 1).

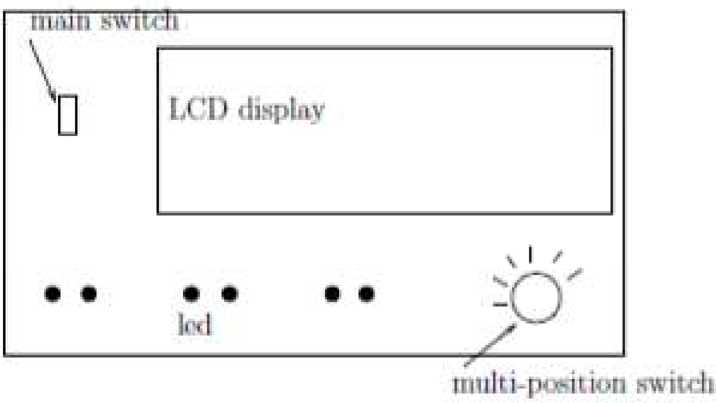

Figure 1: The LCD box

3.2 Remote

3.2.1 Using the remote

The IR receivers of `ANG-med` are located at the front and at the rear of the LCD box. To use the remote you must direct the remote toward one of this receiver. A red led will light if the remote emit a signal.

3.2.2 Changing the battery of the remote

The remote may be used for a long time but still its batteries may have to be changed at some point. After changing the batteries it is necessary to reinitialize the remote:

- press the "SETUP" button of the remote until the red led is lighted continuously
- introduce the code 0002 with the numerical key (when you press a key the led must light off temporarily, when hitting the 4th element of the code it must switch off)

3.3 Batteries

3.3.1 Presentation

`ANG-med` has 2 23Ah batteries that are located at the bottom of the walker. In between these batteries there is small black box with a green led and the *main power switch*. On top of each battery is a switch: **you must never touch this switch!**. Close to this switch there is a LCD display that provides the level of battery charge. In front of the battery you have a set of connectors: USB one and two power connectors that are labeled *charge* and *12V*.

3.3.2 Charging the batteries

To charge the batteries you must:

- set the main power switch to the off position: **never charge the battery with the main power switch in the ON position!**
- unplug the two power connectors denoted *12V*
- plug the two power connectors denoted *charge* to the 2 power supply provided with `ANG-med`

If the batteries are full discharged it may take them about 8 hours to be fully recharged.

3.3.3 Autonomy and low battery signal

Starting from a full battery charge it is expected that `ANG-med` may run in full mode for about 24 hours but this number depends upon the type of exercise that is run by the walker.

`ANG-med` monitor the battery level and will emit a signal toward the control through the communication if the battery level is low. If the battery signal still decreases, then `ANG-med` will automatically shutdown after saving all records of the current exercise.

3.4 The fit-pc computer

The on-board computer of `ANG-med` is a fit-pc. You may only see the front face (figure 2) of this computer. Of particular importance is the ON button of this computer which is located on the left of the front face (it's a tactile button).

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Figure 2: Front and rear face of the fit-pc

4 Subject and caregiver ID

It may be necessary for some exercise to provide the ID of the subject performing the exercise and/or the ID of the caregiver that is managing the exercise. We describe in this section how to recover these ID.

4.1 Providing ID with the walker

The walker is equipped with a RFID reader located in a gray box on the left side of the walker, close to the seat. Presenting a rfid tag to the reader will able to define the ID of the subject. Note that `ANG-med` is provided with special tag that are reserved for the caregivers. .

4.2 Providing ID with the control

to be described by INDES

5 Starting `ANG-med`

- if necessary unplug the batteries power connectors labeled *charge*
- plug in the battery power connectors labeled *12V*
- Before starting `ANG-med` you must decide what type of exercise you want it to run. A very frequently used exercise is the *dynamic walk exercise* that will be described later on. If this is the exercise you want to run set the main switch to the ON position. If you want to run another predefined exercise then put the main switch in the OFF position.
- put the main power switch in the ON position (a green led close to the main power switch should light on)

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- switch on the on-board computer. It will take about 20 seconds before `ANG-med` is fully functional. When ready all the leds of the LCD box should light on for a few seconds, then get off

Note that:

- if you have started `ANG-med` with main switch in the OFF position but want to run the default *dynamic walk exercise* just put the main switch in the ON position
- if you have started `ANG-med` with main switch in the ON position but want to run another exercise than the default *dynamic walk exercise* just put the main switch in the OFF position and restart `ANG-med` (see section 6.3)

6 Starting a predefined exercise

There may be up to 100 predefined exercises loaded in `ANG-med` . They are labeled from 0 to 99. When started with the main switch in the OFF position `ANG-med` will be waiting to receive orders either from the control (if in the connected mode) or from the remote (if in the stand alone mode). An order of special importance is the choice of the predefined exercise that will be run.

6.1 With the remote

To start an exercise with the remote you will have to provide the exercise number:

- use the numerical keys of the remote to provide the exercise number. When a numerical key is hit (say 4) the LCD display should show the message `E:4`. Note that it may happen that the remote believe that a key has been hit twice (in our example the LCD display will show `E:44`). To avoid that use only short pressure on the key. To cancel the sequence use the yellow key at the bottom of the remote and restart
- as soon as the LCD shows the right exercise number push the green key at the bottom of the remote: the exercise will start almost immediately and the LCD display should show on the first line the title of the exercise

6.2 With the control

to be described by INDES

6.3 Restarting

7 Indicators

Indicators are synthetic assessments of the subject functional status. There are specific indicators for each exercise. Note that each indicator has an access level i.e. that some of them are provided only to a caregiver and not to a subject.

7.1 Getting the indicators in the stand-alone mode

Start `ANG-med` with main switch in the OFF position. As soon as you see the message "Waiting" on the LCD press the remote key with a window and line (top left black button). The walker will wait for an exercise number. Introduce it using the numerical key and conclude with the green button (to correct use the yellow button). The LCD will display the available indicator for this exercise, line by line. Move to the next line by using the green button. Use the "exit" key to exit from the report mode.

5

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